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Economic Geology of the

FRENCH GULCH QUADRANGLE

Shasta and Trinity Counties, California

Special Report 85

CALIFORNIA DIVISION OF MINES AND GEOLOGY

ECONOMIC GEOLOGY OF THE

FRENCH GULCH QUADRANGLE

SHASTA AND TRINITY COUNTIES, CALIFORNIA

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With a section on a

GEOPHYSICAL SURVEY OF THE IRON MOUNTAIN MINE

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SPECIAL REPORT 85

CALIFORNIA DIVISION OF MINES AND GEOLOGY
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Abstract

The French Gulch quadrangle since the 1850's has yielded about 4.3 million tons of copper-zinc ore averaging 4.7 percent Cu and 4 to 5 percent Zn, 4 million tons of pyrite used for sulfur, 1.1 to 1.3 million ounces of gold, and 27 million ounces of silver. The copper, zinc, and pyrite, as well as most of the silver and about one-fourth of the gold, have come from massive sulfide deposits. The remaining gold and silver have come from vein deposits. Excluded from the above figures is the gold recovered from placer deposits, the value of which is not known but which may amount to several million dollars.

Rocks range in age from pre-Silurian to Recent. The oldest rocks are actinolite and quartz-mica schists in the southwestern corner of the quadrangle. Successively younger rocks, all probably Paleozoic in age, include the Copley Greenstone, Balaklala Rhyolite, Kennett Formation, and Bragdon Formation. Two plutons probably of Late Jurassic but possibly of Early Cretaceous age—the Mule Mountain stock and the Shasta Bally batholith—intrude the Paleozoic and possibly older rocks. The stock is mainly trondhjemite and albite granite; the batholith is quartz diorite and granodiorite. A belt of gneissic rocks derived from the Copley, Balaklala, and Bragdon Formations occurs along the northeast edge of the batholith. Minor intrusive bodies include sill-like masses of peridotite in the actinolite and quartz-mica schist, and dikes and sills of metagabbro, lamprophyre, aplite, hornblendite, andesite porphyry, quartz porphyry, dacite porphyry, and diorite porphyry. The last four types of porphyry are closely associated with gold deposits in the northern part of the quadrangle.

Postorogenic rocks include those of Cretaceous and Quaternary ages in the southeastern part of the quadrangle. Landslide debris, colluvium and stream gravels of Recent age cover the bedrock in many places throughout the quadrangle.

The northwest-trending Shasta Bally batholith and its aureole of strongly foliated gneiss is the dominant structural feature in the quadrangle. Folds trending N. 40° to 60° E., north, and N. 50° to 80° W. are recognized in the northern part of the quadrangle but most folds are poorly defined and no single fold system is dominant. A broad, low, archlike structure trending eastward through the northern part of the map area is suggested by the outcrop pattern of the Copley Greenstone. A system of east-trending porphyry dikes, gold-bearing quartz veins, and faults, mainly in the Bragdon Formation, parallels the arch just south of its crest. Similarity of some of the dikes to the Shasta Bally batholith suggests that an east-trending salient of the batholith may lie at depth beneath the arch.

The Bragdon Formation is in most places separated from underlying formations by the Spring Creek thrust fault. This pre-intrusive thrust is occupied in many places by porphyry dikes and by lenticular quartz veins.

Normal faults are common in all rock units except the Shasta Bally batholith where they are relatively rare. In the northeastern part of the quadrangle a group of faults striking east to N. 60° E. are mineralized and believed to have been feeder channels for the massive sulfide deposits. Faults striking north to N. 20° E., and N. 20° to 50° W. are present in other parts of the quadrangle.

Precious-metal mining districts in the quadrangle include the French Gulch-Deadwood, Muletown, South Fork, and Whiskeytown. The geology of individual mines in these districts is described. The geology of the Greenhorn massive sulfide mine, which lies several miles west of the West Shasta copper-zinc district, is also described.

Electrical-resistivity, natural-potential, and magnetic measurements were made at the Iron Mountain massive sulfide mine during 1951 and 1952 by C. H. Sandberg. None of the methods gave a unique delineation of the Brick Flat ore body of the Iron Mountain mine. Resistivity was judged to be unsatisfactory. Natural-potential anomalies, probably due to chemical activity in the "gossanized" area, did not outline the ore body. Magnetic readings, by their erratic nature over the mineralized zone rather than any consistent pattern, did outline the mineralized zone, including the ore body.

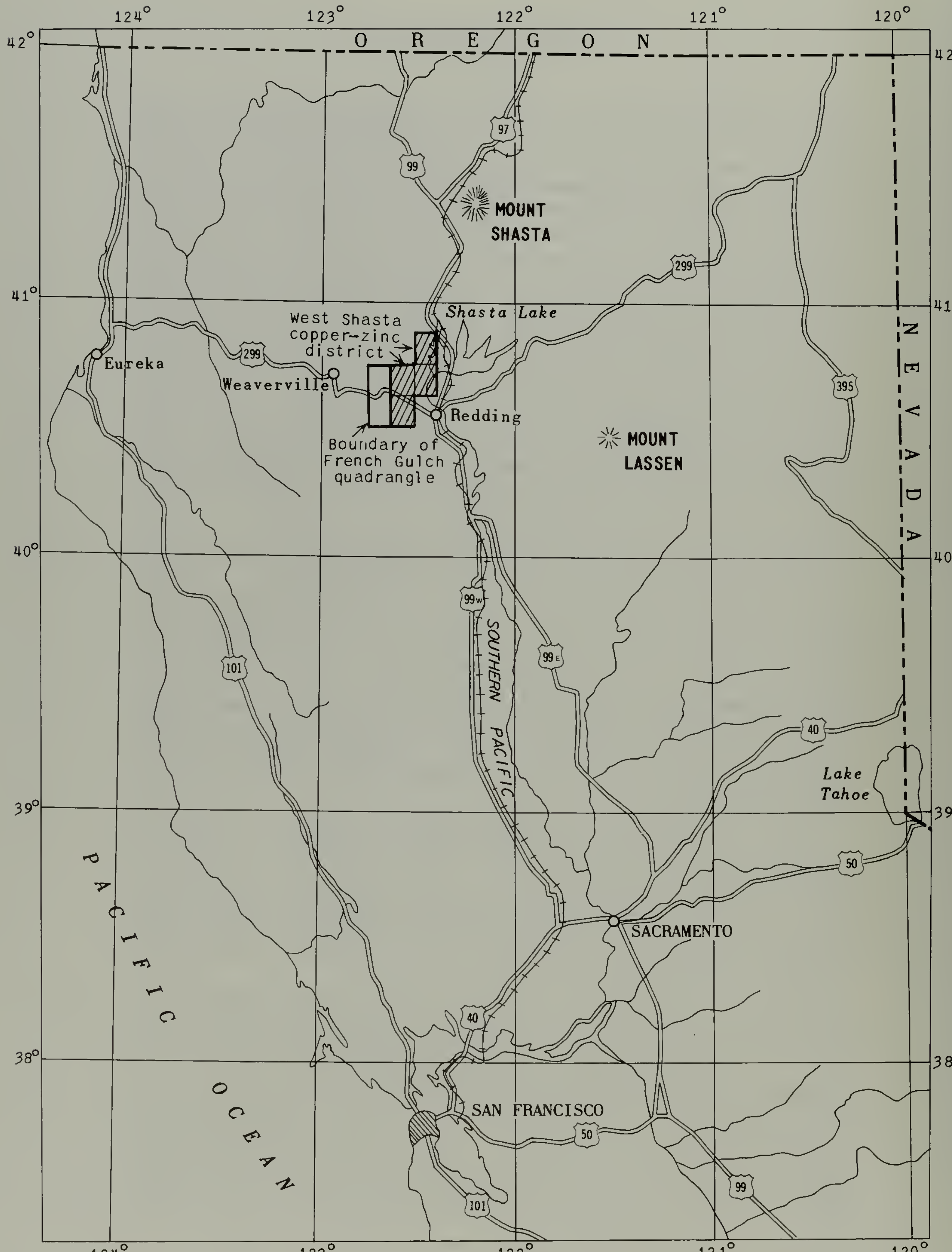

Figure 1. Index map of northern California showing location of the French Gulch quadrangle in relation to the West Shasta copper-zinc district.

Economic Geology of the French Gulch Quadrangle, Shasta and Trinity Counties, California

By John P. Albers

Introduction

Location and economic importance. The French Gulch quadrangle, in Shasta and Trinity Counties, California, is bounded by the 122°30′ and 122°45′ W. meridians and by the 40°30′ and 40°45′ N. parallels (fig. 1). It is almost entirely in the rugged Klamath Mountains at the northwest end of the Sacramento Valley. Maximum relief is about 5,600 feet. Shasta Bally, altitude 6,209 feet, is the highest and most prominent peak in the quadrangle. Clear Creek, which flows from northwest to southeast across the quadrangle and thence into the Sacramento River a few miles beyond the quadrangle boundary, is the dominant stream. Igo and French Gulch are the main settlements. U.S. Highway 299, connecting Redding at the north end of the Sacramento Valley with Eureka on the coast, crosses the quadrangle in an east-west direction, and numerous secondary roads, many of which were built during the 1950's for logging purposes, give ready access to most of the area.

Metal mining has been one of the most important industries in the French Gulch quadrangle for more than 100 years. Copper, zinc, pyrite, gold, and silver are the main mineral products. Estimated production, gathered from various sources and excluding placer gold for which no data are available, is about 4.3 million tons of copper-zinc ore averaging 4.7 percent Cu and 4 to 5 percent Zn, 4 million tons of pyrite used for sulfur, 1.1 to 1.3 million ounces of gold, and 27 million ounces of silver. The copper, zinc, pyrite, and all except about a million ounces of silver have come from the massive sulfide deposits of the West Shasta district. The average percent of copper recovered is not known. Zinc was recovered from only about 500,000 tons of the massive sulfide copper-zinc ore, most of which was mined before the advent of selective flotation. The massive sulfide deposits have also probably yielded about 280,000 ounces of the total gold production. The remaining gold has come largely from gold-bearing quartz veins of the French Gulch mining district.

The principal massive sulfide deposits in the quadrangle are those of the Balaklala, Early Bird, Greenhorn, Iron Mountain, Keystone, and Stowell mines, and the chief gold deposits in quartz veins include the American, Brown Bear, Franklin, Milkmaid, Gladstone, Niagara, and Washington. In addition, the Silver Falls-Chicago Consolidated mine, a vein deposit, has been a fairly important producer of silver. Only the Iron Mountain mine, operated by the Mountain Copper Co., Ltd., was being worked in 1960.

Field work, sources of data, and scope of report. The geology of the eastern half of the French Gulch quadrangle was mapped on a scale of 1:24,000 during the period 1946-1951 as part of a study of the West Shasta copper-zinc district. Kinkel and others (1956) give the results of this work, including a description of all the known massive sulfide deposits, except the Greenhorn. Precious metal deposits occurring within the West Shasta district are not described in that report.

During 1956 and 1957 the western half of the quadrangle was mapped on a scale of 1:48,000 and all available maps and other data on the Greenhorn sulfide deposit and on precious metal deposits were collected from mine owners, supplemented by the mapping of accessible parts of certain mines and by other firsthand observations of the geology in mine areas. The geology of the eastern half of the quadrangle (Kinkel and others, 1956) was generalized to a scale commensurate with 1:48,000 scale mapping, and a few important faults, exposed in roadcuts made since 1951 when field work in the West Shasta district was completed, were added. The resulting geologic map of the entire quadrangle, published herein as plate 1 at 1:62,500 scale, is a composite of mapping done partly on 1:24,000 and partly on 1:48,000 scales.

The geology of the Greenhorn massive sulfide deposit is described in detail here, but the geology of other individual massive sulfide deposits, already given by Kinkel and others (1956), is omitted.

Only parts of the Greenhorn and a few of the gold mines—the American, Summit, and Washington mines, and the Ike Wertz prospect—were accessible for mapping during 1956-1957. Consequently, only a small percentage of the geology shown on the various mine maps was mapped by the present writer. However, all the mine owners contacted were extremely cooperative in furnishing old maps and other information on their holdings and in permitting publication of this information. The maps, especially, have been of great value in helping to decipher the relation of individual deposits and groups of deposits to the general geology of the district. Nearly all are included with this report even though the geologic data on some is scanty or lacking.

The location of mines and prospects is shown in relation to the general geology and topography of the quadrangle on plate 2. Nearly all the mine openings and pits shown were located during the course of field work. A few were plotted from descriptions in old reports and from old maps. The locations of veins were plotted partly from surface exposures and alinement of pits, and partly from projection of veins to the surface from underground workings.

No attempt is made to give exhaustive descriptions of the individual mines and prospects, as adequate data for this sort of treatment are lacking. Many of the brief descriptions given are in fact taken from unpublished mining company reports and from reports of the California Division of Mines and Geology and the U. S. Geological Survey. The principal purpose here is to relate the various deposits to the areal geology and to suggest additional areas that are geologically favorable for prospecting.

Acknowledgments. During the 1956 field season the writer was assisted by Avery A. Drake of the Geological Survey, who is responsible for about a third of the mapping in the western half of the quadrangle. Donald B. Tatlock and William P. Irwin of the Geological Survey each worked for a few weeks during the 1957 season. They helped complete the mapping of the western part of the quadrangle and helped map new roadcut exposures in the eastern part. Drake and Irwin assisted in the mapping of accessible mine openings. The writer is grateful to these men not only for the work they accomplished but also for their stimulating discussions of various geological problems during the course of the field work.

Particular thanks are due to A. R. Kinkel under whose direction the earlier work in the West Shasta district was done and with whom many fruitful discussions of nearly all aspects of the geology of the region have been held over the years.

To the many mine owners in the area who readily supplied maps, private reports, and oral information on mines that are no longer accessible, the writer expresses his appreciation. Included in this group are E. M. Clark, owner of the Niagara group of mines; Don Carlson, lessee, and Mrs. Marion G. Fondahn, owner of the Summit mine; E. E. Erich, owner of the Brown Bear mine; W. K. Gonyea, owner of the Greenhorn mine and Clayton T. McNeil, his representative; J. H. Scott, owner of the Washington mine; and Herbert R. Westlund, owner of the Franklin and Milkmaid mines. The Miami Copper Company held an option on the Greenhorn mine for several months during 1956-1957 and information on the geology of the property was given by their geologist, Joseph E. Fowells. Henry Carter, caretaker at the Washington mine and a miner with long experience in the French Gulch district, kindly guided the writer to the Washington mine workings and supplied information on the Washington and nearby prospects. We are also indebted to Redding Pine Mills, Inc., to Phelps Dodge Corporation, and to Shasta Minerals and Chemical Company for allowing access on private roads in various parts of the quadrangle.

The study has also benefited from field conferences with Thomas E. Gay, Jr., Gordon B. Oakeshott, and J. C. O'Brien (retired) of the California Division of Mines and Geology.

The work is part of a cooperative project between the U. S. Geological Survey and the California Division of Mines and Geology.

Description of geologic formations

The older rocks of the quadrangle include quartz-mica schists, amphibole schists, mafic and felsic volcanic rocks, and shaly and conglomeratic sedimentary rocks that range in age from pre-Silurian and possibly Precambrian to Mississippian. During Late Jurassic or possibly Early Cretaceous time these rocks were intruded by two large plutons, the Mule Mountain stock and the Shasta Bally batholith, by sill-like masses of ultramafic rock, and by numerous dikes and sills ranging in composition from lamprophyre to quartz porphyry. In most places along the border of the Shasta Bally batholith the schists and volcanic and sedimentary rocks were changed to gneiss and amphibolite by contact metamorphism. In the extreme southeastern part of the quadrangle sedimentary rocks of Cretaceous and Pleistocene age overlie the older rocks with marked unconformity. Bedrock geology is effectively obscured by Recent landslide debris and colluvium on many hill slopes in the northern part of the quadrangle and by alluvium in some stream valleys.

Only a brief description of the formations, with main emphasis on those that are hosts for the mineral deposits is given here. For a more complete description the interested reader is referred to reports on the geology of the French Gulch quadrangle (Albers, 1964) and on the West Shasta copper-zinc district (Kinkel and others, 1956).

Abrams Mica Schist and Salmon(?) Hornblende Schist

The oldest rocks exposed are the schists in the extreme southwestern part of the quadrangle. These schists are probably pre-Siluvian and possibly of Precambrian age, but precise age data are lacking. Most of the schists are coarsely crystalline but some are fine grained. Albite-actinolite schist and albite-quartz-muscovite-chlorite-epidote schist in roughly equal proportions are interlayered in sheets a few feet to a few hundred feet thick. The schists belong in part at least to the Abrams Mica Schist of Hershey (1901) but may also be correlative in part with the Salmon Hornblende Schist (Hershey, 1901). Interlayering of mica schist and actinolite schist suggests a transitional zone between the Abrams and the Salmon(?). The Abrams and Salmon(?) Formations crop out over a large area in the Weaverville quadrangle just west of the French Gulch quadrangle and their relations have been described by Irwin (1960a). No mineral deposits are known in these schists in the French Gulch quadrangle.

Copley Greenstone

Much of the northeastern and eastern part of the quadrangle is underlain by the Copley Greenstone, which consists principally of intermediate and mafic volcanic rocks. These rocks are largely altered to keratophyre*, meta-andesite, and spilite*, but in most places they retain their original structures and textures. Quartz keratophyre * probably derived from dacite and rhyolite forms a subordinate part of the Copley. The formation is at least 3,700 feet thick at its best exposed section in the Modesty Gulch-Grizzly Gulch area, but the base of the formation has nowhere been recognized.

The Copley is separated from the schists of the Abrams and Salmon(?) Formations by the Shasta Bally batholith and by a zone of gneissic rock and amphibolite in the aureole of the batholith. Consequently, the relation of the Copley to the Abrams and Salmon(?) Formations, which presumably underlaid it, is obscure. The Copley Greenstone is conformably overlain by the Balaklala Rhyolite, and the contact between these two units is in places transitional. The Copley contains sheets of quartz keratophyre identical to that of the Balaklala Rhyolite at many places; some of these are dikes and sills, and some are flows and tuff beds. Likewise, the Balaklala Rhyolite contains sheets of greenstone similar to the Copley. Locally, as in upper Modesty Gulch (a tributary of Grizzly Gulch), volcanic breccia consisting of greenstone and quartz keratophyre bombs and fragments in a matrix of greenstone overlies the Copley Greenstone and by an increase in the percentage of quartz keratophyre fragments grades upward into the main mass of the Balaklala Rhyolite. These relations indicate that the eruption of felsic lava occurred intermittently during Copley time, and that the eruption of intermediate and mafic material likewise continued into Balaklala time. Thus the contact between Copley and Balaklala rocks is transitional and is arbitrarily drawn at the lower limit of the main mass of quartz keratophyre. However, this contact may not be at the same position in the time-stratigraphic sense throughout the area.

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* The terms spilite, keratophyre, and quartz keratophyre are petrographic terms applying to altered rocks in which the feldspar is altered to albite. Thus, spilite is like basalt, keratophyre is like andesite, and quartz keratophyre is like dacite or rhyolite, except that in all three, the feldspar is albitized and ferromagnesian minerals are commonly altered to chlorite.

In the western part of the quadrangle the Balaklala and Kennett(?) Formations are missing and the Copley is discordantly overlain by the Bragdon Formation.

As the Copley Greenstone and Balaklala Rhyolite are interlayered and intertongued, the two formations are about the same age. The Balaklala, for reasons given in the following section, is considered to be Middle Devonian; the upper part of the Copley is probably also Middle Devonian, although the lower part may be older.

The Copley Greenstone contains no important mineral deposits, although it is cut in many places by quartz veins from which gold was extracted in small quantities. In parts of the French Gulch district tabular masses of quartz along the contact between the Copley and Bragdon Formations have yielded gold in fairly substantial quantity, particularly near intersections with steeply dipping quartz veins in the greenstone.

Balaklala Rhyolite

The only important host rock for the massive sulfide deposits in the French Gulch quadrangle is the Balaklala Rhyolite. This formation consists largely of silicic volcanic flows and pyroclastic rocks, but includes subordinate dikes and sills.

The Balaklala has been subdivided into a lower, a middle, and an upper unit by Kinkel and others (1956, p. 17-32). This subdivision is based on the presence or absence of quartz phenocrysts, and on their average size.

A generalized lithologic description of the Balaklala Rhyolite, modified from Kinkel and others (1956, p. 20), is given below:

	Thickness (feet)
Transition zone to Kennett(?) Formation:	
Tuff containing some quartz clasts and phenocrysts more than 4 mm in diameter and felsic tuff interlayered with thin shale beds	0– 300
Balaklala Rhyolite:	
Upper unit, coarse-phenocryst quartz keratophyre containing quartz phenocrysts more than 4 mm in diameter. Transition zone at the base is locally composed of coarse-phenocryst felsic tuff and breccia	0–1,400
Middle unit, predominantly flows of medium-phenocryst quartz keratophyre, and pyroclastic material with quartz phenocrysts and clasts 1 to 4 mm in diameter, but contains many small flows of nonporphyritic quartz keratophyre; widespread beds of pyroclastic material in the upper part of the unit; contains small flows of mafic lava	0–1,500
Lower unit, predominantly nonporphyritic quartz keratophyre flows and pyroclastic material, but includes a few flows of quartz keratophyre with 1 to 4 mm phenocrysts and a few flows of mafic lava *	0–2,000
Transition zone to Copley Greenstone:	
Mixed mafic and felsic pyroclastic rocks	0– 150

* These flows of mafic lava are arbitrarily assigned to the Copley Greenstone in the present report.

These lithologic units were mapped separately on the 1:24,000 scale map by Kinkel and others (1956), but on plate 1 of this report most of them are combined. The coarse-phenocryst quartz keratophyre, which forms the upper unit, but also occurs lower in the section, is mapped separately, as are the fine-grained pyroclastic beds.

The petrography of the Balaklala Rhyolite is discussed in detail by Kinkel and others (1956, p. 22-31). The dominant minerals, and in many specimens virtually the only minerals, are quartz and albite. They form phenocrysts and make up most of the groundmass. Next in importance is fine-grained white mica, which is fairly abundant in sheared facies but scarce elsewhere. Chlorite is also locally common but in general is a minor constituent, as are epidote, apatite, magnetite, sphene, and clay minerals. Quartz and feldspar phenocrysts range from euhedral to anhedral in different specimens but subhedral types are most common. Most thin sections show felty groundmass textures, but trachytic and pilotaxitic textures are not rare. Myrmekite-like intergrowths of quartz and feldspar are common, and microspherulitic structures were seen in some specimens. The pyroclastic rocks are about the same mineral composition as the flows although the proportions of various minerals differ, and alteration products, particularly fine-grained white mica and clay minerals, are generally more abundant.

The Balaklala ranges in thickness from 0 to about 3,000 feet in the French Gulch quadrangle. Its maximum thickness is about 3,500 feet in the Mammoth Butte area east of the quadrangle (Kinkel and others, 1956, p. 18). The thickness differs greatly from place to place owing to the volcanic origin of the formation and to the siliceous character of its component flows.

The stratigraphic relation of the Balaklala to adjacent formations is one of conformability. It intertongues with and is transitional to the underlying Copley Greenstone, as has already been described, and the uppermost tuffaceous rocks of the Balaklala are interbedded with and grade into shaly tuff and shale of the overlying Kennett Formation (Kinkel and others, 1956, p. 19) at the type locality of the Kennett in the Backbone Creek area northeast of the French Gulch quadrangle. The Balaklala similarly intertongues with and grades into a cherty shale that is correlated with the Kennett Formation in the French Gulch quadrangle. Furthermore, tuff identical to that of the Balaklala seems to grade upward into shaly rocks of the Bragdon Formation at a few places in the western part of the quadrangle, particularly east of Tower House and in the Right Fork of French Gulch (pl. 1). Elsewhere the Bragdon Formation seems to be in fault contact with the Balaklala. The Balaklala is considered to be of Middle Devonian age.

All the known massive sulfide deposits in the quadrangle are in the Balaklala Rhyolite and most are in the upper part of the middle unit.

Kennett(?) Formation

A discontinuous unit of cherty black shale that resembles the cherty shale of the lower part of the Kennett Formation at its type locality in the Backbone Creek area is between the Balaklala and Bragdon Formations in the northeastern part of the quadrangle. The cherty shale is highly contorted and faulted, and because of this the thickness of the unit is difficult to ascertain, but it is estimated to range from a few tens of feet to about 200 feet. Locally the cherty shale is interbedded with tuff of the Balaklala Rhyolite type and seems to grade downwards into the Balaklala. No contacts with the overlying uncontorted shale of the Bragdon Formation were seen, but this contact is inferred to be a thrust fault of unknown magnitude.

No fossils were found in the cherty shale and it was correlated with the Kennett Formation, of Middle Devonian age only on the basis of lithology and stratigraphic position (Kinkel and others, 1956, p. 36). However, contorted cherty shale is also present well above the lowest exposed part of the Bragdon north of Backbone Creek northeast of the French Gulch quadrangle (Kinkel and others, 1956, geologic map), and thus the cherty shale here described may be altered Bragdon rather than Kennett. The cherty black shale unit contains no known mineral deposits.

Bragdon Formation

The Bragdon Formation, of Mississippian age, underlies much of the northern part of the French Gulch quadrangle. Many of the gold deposits of the French Gulch-Deadwood district are in the Bragdon so it is an important unit from an economic standpoint. Hershey (1904, p. 347-360) named the formation from exposures at the settlement of Bragdon, on the Trinity River about 10 miles north of the French Gulch quadrangle.

Shale, mudstone, and siltstone are the principal rocks of the lower part of the Bragdon; impure sandstone, conglomerate, and mafic tuff are subordinate. In the upper part of the Bragdon, coarse clastic rocks, including sandstone, grit, and conglomerate, are interbedded with and are about equally abundant as shaly rocks. On the geologic map (pl. 1) the formation has been divided into a lower and an upper unit on the basis of this difference in lithology. The base of the upper unit is placed at the base of the lowest prominent and continuous conglomerate bed.

The Bragdon Formation in places rests with structural discordance on the Copley Greenstone or is separated from it by intrusive sills or quartz veins. Elsewhere, it overlies the Balaklala Rhyolite or contorted cherty shale of the Kennett(?) Formation. In a few places, flows of rhyolitic rock mapped tentatively as Balaklala are included in the Bragdon; in the Hoadley Peaks area the Bragdon is intruded by the Shasta Bally batholith.

Contacts between the Bragdon and Copley Formations were seen only in a few places, notably in mine workings, roadcuts, and prospect pits in the western part of the quadrangle. In virtually all these exposures a few feet to a few tens of feet of the Bragdon are sheared and faulted; commonly the shearing is about parallel to the contact. More commonly the two formations are separated by intrusive rock or quartz veins. No undisturbed contacts of Bragdon on Copley were seen. The contact between greenstone and the less competent shaly rocks of the Bragdon probably is a thrust fault, developed mainly in the incompetent rocks of the Bragdon. The presence in many places (pl. 1) of sill-like sheets of intrusive rock or of quartz veins, probably of Late Jurassic age, indicates that this contact was a favorable locale for intrusion and mineralization and further suggests that it was a plane of structural weakness.

Diller (1906, p. 3) considered the contact between the Bragdon and Kennett Formations to be unconformable because of the presence of cobbles of fossil-bearing limestone, derived from the Kennett, in conglomerate beds of the Bragdon. His conclusions were based chiefly on relations in the Redding 30-minute quadrangle east of the present map area. In the French Gulch quadrangle, 1) the presence of beds of quartz keratophyre tuff interbedded with mudstone, 2) the gradation of tuffaceous mudstone downward into tuff of the Balaklala Rhyolite in some localities, and 3) the presence locally of sheets of extrusive quartz keratophyre interbedded in the lower unit of the Bragdon indicate either that: (a) the eruption of silicic volcanic flows and pyroclastics of the Balaklala Rhyolite continued throughout Kennett and into Bragdon time with no significant erosional break, or (b) that some of the rocks presently identified as Bragdon in the French Gulf quadrangle are correlative with the Kennett rather than with the Bragdon. The first interpretation is here preferred because the lithology of the sedimentary rocks is in general more like the Bragdon than the Kennett, and the lithology of the quartz keratophyre is similar to the Balaklala.

The thickness of the Bragdon Formation is probably about 6,000 feet, of which 4,500 feet constitutes the lower unit, and 1,500 feet constitutes the upper. These thicknesses are only rude approximations at best, as the top of the Bragdon is not exposed in the French Gulch quadrangle, and as the formation is inferred to be bounded on the bottom by a thrust fault.

About 90 percent of the lower unit is dark-gray shale, mudstone, and siltstone; interbedded with these fine-grained rocks are lenses of sandstone, graywacke, conglomerate, tuff, and tuffaceous sandstone that make up the remaining 10 percent of the unit. The principal components of the shales, mudstones, and siltstones are quartz, clay minerals, fine-grained white mica, carbonaceous material, and chert particles. Feldspar clasts, quartz phenocryst clasts, chert, and, rarely, fragments of volcanic rocks are the important constituents in the coarser clastic rocks.

The most distinctive rocks in the upper unit of the Bragdon are the conglomerate beds, which consist predominantly of vari-colored angular to subangular chert pebbles and fragments. Limestone, sandstone, shale, vein quartz, and rhyolite also occur as fragments in the conglomerate but are much less common than chert. The coarsest beds contain boulders as much as a foot in diameter and are characterized by abundance of limestone and other noncherty fragments; more commonly the size of fragments ranges from half an inch to about 2 inches in diameter and the material is predominantly chert. Most conglomerate beds are 10 to 20 feet thick but the overall range is from a few inches to possibly 100 feet. Some beds have been traced for several miles along strike, whereas others could be traced for only a few hundred feet where they either lens out or are cut off by faults. Only rarely is the lithology of a particular bed distinctive enough to be identified with confidence from one outcrop to the next.

The Bragdon Formation has been assigned a Mississippian age by Diller (1906, p. 3). No fossils were found during the present investigations.

A belt of phyllite having a maximum outcrop width of nearly a mile (pl. 1) extends from Crystal Creek northwestward almost to the western edge of the quadrangle. The phyllite lies northeast of, and mostly adjacent to a belt of muscovite-biotite gneiss, but locally it is separated from the gneiss by the Balaklala Rhyolite. Composition, relict structures, distribution, and gradational relations to the Bragdon Formation indicate derivation of the phyllite from shaly rocks of the Bragdon. Most of the phyllite was derived from the lower unit of the Bragdon, but in the upper part of Trail Gulch the phyllite contains conglomerate that is correlated with the upper unit. Abundant fine-grained white mica parallel to schistosity gives the rock a silky sheen, and irregularly distributed small spherical or elliptical bodies of carbonaceous material and quartz about 1 mm in diameter impart a knotty appearance. In a few places where bedding is discernible in the phyllite, it is parallel to schistosity, but in other places it is cut at a high angle by schistosity.

Mule Mountain stock

A stock consisting mostly of medium- to coarse-grained light-colored granitic rock (trondhjemite and albite granite) crops out in the eastern part of the French Gulch quadrangle. The stock is roughly elliptical, being about 10 miles long and 5 miles wide, and elongate in a northerly direction. Only the western half is in the French Gulch quadrangle (pl. 1). The stock is part of Diller's (1906, p. 8) hornblende quartz diorite. It was named the Mule Mountain stock by Hinds (1933, p. 105) for its prominent exposure on Mule Mountain.

Most of the stock is coarse-grained holocrystalline rock with a granitoid texture. Quartz (plagioclase, and epidote are the principal minerals; chlorite, hornblende, biotite, and opaque minerals are subordinate. The proportion of the various minerals differs markedly from place to place owing partly to the original heterogeneity of the stock and partly to subsequent alteration. The average grain size is about 2 mm, but some facies of the rock have irregular masses of glassy quartz as much as 10 mm in diameter that superficially appear to be phenocrysts. Most of the stock is light colored owing to its low content of ferromagnesian minerals, and the siliceous albite granite facies is generally a brilliant white with sparse splotches of green epidote as much as 6 mm in diameter. This facies is prominently exposed in roadcuts along U. S. 299 near the eastern edge of the quadrangle.

A large pendant of Balaklala Rhyolite about 4 miles long (pl. 1) projects into the stock, which also contains numerous inclusions of Copley Greenstone and Balaklala Rhyolite measuring a few hundred to a few thousand feet in maximum dimension. The inclusions of greenstone show various stages of replacement or assimilation by the granitic rock. No chilled contacts were seen. Most of the large inclusions have a relict layering which is concordant with other blocks and with the country rock surrounding the stock, indicating the blocks were not detached from the roof during emplacement of the pluton. These features, along with the presence of replacement dikes and the heterogeneous character of the stock, especially near pendants and inclusions, suggest that granitization was an important if not dominant mechanism by which the Mule Mountain stock was emplaced.

About 50 percent of the stock in the French Gulch quadrangle is trondhjemite, consisting mainly of quartz and plagioclase, and subordinate mafic minerals. Most of the rest of the stock within the quadrangle is albite granite that has gradational contacts with the trondhjemite and that forms irregular, mostly elongate masses of nearly white rock consisting of quartz, albite, and minor epidote. Petrographic, chemical, and field data indicate formation of the albite granite largely from trondhjemite by either hydrothermal or deuteric alteration. The spatial relation of some masses of albite granite to inclusions of Balaklala Rhyolite and the mechanical and mineralogical similarity of the two rocks suggests, however, that some albite granite may have formed by recrystallization of Balaklala Rhyolite.

Metamorphism resulting from the emplacement of the Mule Mountain stock is restricted to recrystallization of Copley Greenstone in some areas to granular amphibolite and epidote amphibolite for a few feet to a few tens of feet from the contact. In many places along the contact little or no metamorphism seems to have taken place.

The age of the Mule Mountain stock is inferred to be Late Jurassic (Kinkel and others, 1956, p. 47; Albers, 1964, p. J36), but may be as young as Early Cretaceous.

Peridotite

Two tabular elongate masses of slightly serpentinized peridotite crop out in the southwestern part of the quadrangle (pl. 1). These bodies strike northwest parallel to the enclosing gneiss and schist. The larger one on the north side of Jerusalem Creek, has an outcrop width of about a third of a mile and widens to nearly a mile at Bully Choop Mountain just west of the quadrangle boundary. The smaller peridotite mass southwest of Jerusalem Creek has an outcrop width of about 100 feet. Crude banding is widespread in the peridotite and locally, near the contact, the banding parallels the foliation of enclosing rocks. Olivine, serpentine minerals, and augite are the principal mineral components of the peridotite.

Shasta Bally batholith

Most of the southwestern part of the French Gulch quadrangle is underlain by the Shasta Bally batholith of light-colored quartz diorite and granodiorite. The batholith, named by Hinds (1933, p. 105), is markedly elongate in a N. 45° W. direction and extends northwestward and southeastward beyond the quadrangle boundaries. Its total exposed length is about 30 miles, according to Hinds (1933, p. 105), and its maximum width is about 9 miles. At least six satellites, correlated with the batholith on the basis of lithology, crop out in the southeastern part of the quarangle (p. 1). The largest, called the Clear Creek plug, underlies a little more than 1 square mile.

The batholith is concordant with foliation in gneissic wall rocks along its northeast side. The rocks along the northeast border are mostly amphibolite and banded gneiss derived by contact metamorphism from Copley Greenstone, Balaklala Rhyolite, and Bragdon Formation. Foliation in these rocks dips northeast at angles ranging from 40° to 75° concordant with the batholith contact and its planar structure. Contacts between the batholith and wall rocks are everywhere sharp. Along its southwest side, the batholith is slightly discordant and is bounded by a belt of dikes, sills, and coarse breccia a few hundred feet wide. The breccia consists mostly of blocks of gneiss, schist, and sparse peridotite; the matrix is equigranular coarse-grained diorite. Foliation in the gneissic rocks that lie just west of the belt of dikes and breccia dips northeastward toward the batholith at angles of 50° to 80°, whereas the southwest edge of the intrusive mass as well as a weakly defined planar structure within it, dip 80° to 90°. Viewed broadly, the Shasta Bally batholith therefore seems to have the form of a northwest-trending, east-dipping arch with a steep discordant southwest limb and a less steep concordant northeast limb. It is inferred to widen gradually with depth. A salient of the batholith is thought to extend eastward beneath the zone of porphyry dikes and sills in the northwestern part of the map. This will be further discussed in a later section.

The batholith is in general a fairly homogeneous mass but three facies were distinguished in the field—a coarse-grained biotite facies, a fine-grained biotite facies, and a biotite-hornblende facies. Composition ranges from quartz diorite to granodiorite.

Plagioclase, quartz, and orthoclase, along with biotite and hornblende, are the chief minerals. The orthoclase commonly forms very irregular, optically continuous crystals as much as 5 mm in diameter interstitial to other minerals and contains other minerals as inclusions. It makes up from 1 to about 10 percent and averages about 5 percent of the rocks, which are close to the dividing line between quartz diorite and granodiorite.

Hornblende diorite and gabbro containing as much as 40 percent hornblende and less than 5 percent quartz are common in the southeastern part of the quadrangle near the borders of the batholith and in satellite bodies.

The batholith, like the Mule Mountain stock, is commonly deeply weathered except in the bottoms of canyons and on the main ridges. But unlike the Mule Mountain stock, which is extensively albitized and silicified, the Shasta Bally batholith is but little affected by hydrothermal or deuteric alteration.

Mode of emplacement and age. The Shasta Bally batholith is inferred to have emplaced itself mainly by forcible injection and to some extent by piecemeal stoping. Apophyses of the batholith cut the Mule Mountain stock as well as the Bragdon Formation and older rocks. The batholith is overlain nonconformably by rocks of late Early Cretaceous age. A potassium-argon age of 134 m.y. for the batholith has been determined by Curtis and others (1958, p. 5). Ages of 81, 97, and 101 m.y. by the lead-alpha method have been reported by Jaffe and others (1959), but these last three ages are incompatible with other geologic evidence. The batholith is tentatively assigned a Late Jurassic or possibly Early Cretaceous age.

Minor intrusive bodies

Dikes and sills of various kinds of igneous rock, including metagabbro, lamprophyre, aplite, hornblendite, andesite porphyry, dacite porphyry, diorite porphyry, and quartz porphyry, cut the plutonic and older rocks of the quadrangle. The last three types are the only ones of economic significance and the only ones discussed in this report.

Light-gray to white quartz porphyry, commonly containing "biotite" crystals, intrudes the Copley and Bragdon Formations in the northwestern part of the quadrangle. The largest masses of this porphyry are sill-like bodies a few tens of feet thick and up to a mile long, intruded mainly along the contact between the Copley and Bragdon Formations in the Franklin and Milkmaid mines area in French Gulch. Ferguson (1914, p. 31) called this rock soda granite porphyry in his description of the gold lodes of the Weaverville 30-minute quadrangle.

In its texture and mineralogy, this quartz porphyry is similar to the quartz porphyry of the Balaklala Rhyolite except that it generally contains alteration products pseudomorphous after phenocrysts of biotite (?) which are absent in the quartz porphyry of the Balaklala. The pseudomorphs consist of secondary fine-grained white mica, calcite, epidote, sphene, leucoxene, and magnetite. Quartz and albite are the dominant minerals in the quartz porphyry dikes.

"Birdseye" porphyry. The most common dike rocks in the quadrangle are light-gray porphyries containing abundant phenocrysts of plagioclase, hornblende, biotite, and locally quartz in a sugary to aphanitic groundmass. These porphyries are most common as dikes and sills in the Bragdon Formation, particularly in the lower part of the Bragdon near the gold deposits (pls. 1, 2). Local miners have applied the name "bird's-eye porphyry" to these dike rocks (Ferguson, 1914, p. 31), probably because the centers of the zoned feldspar phenocrysts commonly weather out leaving a depression that somewhat resembles the pupil of an eye.

The "birdseye" porphyry ranges widely in composition, from non-quartzose diorite porphyry, through porphyry containing sparse rounded to lobate phenocrysts of quartz, to dacite porphyry containing abundant quartz phenocrysts. In places both these types are cut by a network of albite veinlets, and locally they are completely albitized.

In Mill Gulch, in the northwestern part of the quadrangle, a dike of coarse-grained biotite-hornblende quartz diorite with a granitic texture intrudes the Bragdon Formation. This dike is virtually identical to the biotite-hornblende facies of the Shasta Bally batholith in texture and composition and is inferred to be an offshoot from the batholith. The mineralogic similarity of other dikes of diorite porphyry, dacite porphyry, and quartz porphyry to this coarse-grained dike and to the batholith suggest a genetic relationship despite textural differences. A salient from the batholith is therefore inferred to extend from beyond the western boundary of the quadrangle near Deadwood (pl. 1), eastward at least to the vicinity of Clear Creek north of the village of French Gulch (Albers, 1961).

The "birdseye" porphyry dikes occur along faults, joints, and bedding planes. They are cut by younger faults and locally by lamprophyre dikes and quartz veins. In places in the French Gulch mining district they are intruded along the same structure as the quartz porphyry dikes described in the previous section. The relative age of the "birdseye" porphyry and quartz porphyry dikes could not be established on the basis of crosscutting relationships, but the latter seems to be more extensively altered and therefore is thought to be older.

Cretaceous rocks

The post-orogenic marine sedimentary rocks in the French Gulch quadrangle are well-cemented sandstones and conglomerates of Cretaceous age that crop out in a small area near the southeast corner of the quadrangle (pl. 1). These were mapped by Kinkel and others (1956, p. 41) as the Chico Formation. Recent work by Peter Rodda, University of California at Los Angeles (written communication, 1957), indicates that this conglomerate and sandstone belongs to Murphy's (1956) Ono Formation of Early Cretaceous age.

Red Bluff Formation

Coarse, poorly to well-cemented gravels lithologically similar to the Red Bluff Formation (Diller, 1906, p. 6) crop out in the extreme southeastern part of the quadrangle and at two localities along Clear Creek between Tower House and French Gulch. The gravel consists of well-rounded boulders and cobbles of various rock types, in an iron-stained matrix of sand and clay. This gravel is correlated with the Red Bluff Formation of Pleistocene age on the basis of lithology and degree of cementation. It is distinguished from younger stream gravels mainly by its reddish color and by its position on benches well above the present stream levels.

Unconsolidated deposits

Unconsolidated deposits of recent age include slope wash or colluvium, landslide debris, and stream gravels. Large parts of nearly every mountain and hillslope in the area are covered by slope wash, but in most places careful examination of the float and its distribution with respect to sparse outcrops enables one to map bedrock with a fair degree of confidence. Therefore, only where slope wash effectively obscures the bedrock and prevents its identification is it shown on the geologic map (pl. 1).

Landslides are difficult to distinguish in some places from slope wash and locally are continuous with some areas of wash. However, almost all the areas mapped as landslide are on steep hillsides and are topped by a topographic bench that is either horizontal or slopes gently toward the hill.

Unconsolidated alluvial gravels occupy parts of the larger stream beds and are found locally in the smaller streams. The largest area of such gravels is in the upper part of Clear Creek and extends from near Tower House approximately to the northern edge of the quadrangle. These gravels have been dredged for gold, and in Whiskey Creek and a few other places smaller areas of gravels have been sluiced for gold.

Structure

The northwest-trending Shasta Bally batholith and its aureole of strongly foliated gneiss are the dominant structural features in the French Gulch quadrangle. East of the batholith is a wide belt of metavolcanic rocks that dip generally eastward and define a broad irregular bend around the Mule Mountain stock in the eastern part of the quadrangle (pl. 1). This bend is also reflected in the orientation of a pendant of Balaklala Rhyolite and detached inclusions of the Balaklala and Copley Formations within the stock. Overlying the metavolcanic rocks with marked structural discordance and probably as a thrust plate is the large mass of Bragdon Formation that occupies most of the northern part of the quadrangle.

Viewed broadly, the quadrangle occupies a critical position where the regional structural trend changes from northwest to north-northeast (Albers, 1964, fig. 5). The northwest trend, shown by the batholith and nearby rock units, dominates in the southern and western parts of the quadrangle and probably represents the prevailing trend of basement rocks beneath younger rocks in the Sacramento Valley southeastward to the northern Sierra Nevada. A north-northeast trend dominates in the northeastern part of the quadrangle and an extensive area to the north and northeast. It is well shown by the strike of various rock units and by the strike of schistosity northeast of Whiskeytown. The juncture of the northwest and north-northeast regional trends is not sharply angular but instead forms an arcuate curve concave towards the east-northeast. This seems to be part of the same structural feature to which Irwin (1960b), describing the adjoining region to the west, has applied the name Klamath arc.

Although the Klamath arc is fairly simple as viewed on a regional scale, the structure within the inflection is complex on the scale of the French Gulch quadrangle. Folds of three trends have been recognized, and numerous shear zones of diverse trends are marked by a prominent schistosity which itself has locally been drag folded. In addition, the rocks are disrupted by a thrust fault at the base of the Bragdon Formation and by many high-angle normal faults.

Cleavage and schistosity

In many places the Copley Greenstone and Balaklala Rhyolite are strongly schistose; in other places they have only a weak cleavage; and in still others they are massive. The schistose rock in the Copley and Balaklala Formations is characterized by parting planes spaced mostly 1 mm or less apart; thin sections show that each parting plane is marked by an abundance of fine-grained platy minerals oriented about parallel to the parting plane. Between parting planes platy minerals are scarce, and in places the original igneous texture of the rock is retained. Field mapping shows that some of these schistose rocks are in discrete zones, separated from each other by massive rock or rock with only weak cleavage. Limits of most zones of schistose rocks are too indefinite and ill-defined to show on the geologic map (pl. 1). In places, schistose rocks are crumpled and drag folded and are cut by a younger slip cleavage at a high angle to schistosity.

Weak cleavage at an angle to bedding cleavage is present locally in shaly rocks of the Bragdon Formation in the north-central and northwest parts of the quadrangle, and a weak schistosity is present in the fine-grained phyllitic facies of the Bragdon near the Shasta Bally batholith. Virtually all the cleavage and schistosity in the Bragdon strikes northwest and dips northeast.

The coarse-grained schist in the southwest corner of the quadrangle has a pervasive schistosity that reflects the complete recrystallization of the rock. Coarsely crystalline platy minerals are concentrated along parting planes spaced about 0.1 mm apart, and the nonplaty minerals between parting planes show typical crystalloblastic forms.

Foliation

Most of the gneissic rocks in the aureole of the Shasta Bally batholith have a prominent secondary foliation caused by the marked segregation of light- and dark-colored minerals in discrete layers a few millimeters to several inches thick. This foliation or banding parallels the batholith contacts and is straight and persistent along strike. The lack of contortion of the banding, along with the finer grain size and more banded character, distinguishes the gneiss of the aureole from the schists in the extreme southwest corner of the quadrangle.

Folds

Folds trending N. 40° to 60° E., north, and N. 50° to 80° W. have been recognized in the quadrangle. All the larger ones are open folds.

The open folds that trend N. 40° to 60° E. are between Whiskeytown and Sugarloaf Mountain and in the upper part of Dry Creek west of Whiskeytown (pl. 1). These folds are revealed mainly by the outcrop pattern of the Copley Greenstone and Balaklala

Rhyolite, and by a few bedding attitudes in tuff layers. The most clearly defined northeast-trending fold is a broad anticline whose core, marked by the Copley Greenstone, lies just north of Iron and Sugarloaf Mountains. The elongate mass of Balaklala Rhyolite extending northeastward through Iron and Sugarloaf Mountains may be a syncline, or a combination syncline and graben.

The only fold that trends north is a syncline in the Bragdon Formation. The trough of this syncline was traced from about three-quarters of a mile north of Merry Mountain to the west side of peak 3195, south of Shirttail Peak. The syncline could not be recognized in the Copley Greenstone beneath the Bragdon.

Folds that trend N. 50° to 80° W. are present in the Bragdon Formation in the northwestern part of the quadrangle; a few were recognized east of Shirttail Peak in the north-central part of the quadrangle. These folds are defined by opposed bedding attitudes. Most of the folds do not seem to persist for more than a few thousand feet along strike and none can be traced into rocks underlying the Bragdon. One fold, east of Hoadley Peaks, is shown on the map as extending for about 3 miles, but evidence for extending it this far is scanty.

In addition to the northwest folds that affect the Bragdon Formation, a northwest-trending anticline is indicated by opposed attitudes of the schistosity of the coarse-grained schist in the extreme southwestern part of the quadrangle. The axis of this anticline is about in Jerusalem Creek, and the fold apparently continues northwest and southeast beyond the limits of the quadrangle.

Drag folds. Drag folds ranging from a few inches to a few feet in wave length are fairly common in four localities: (a) the faulted, probably synclinal, northeast-trending body of Balaklala Rhyolite extending through Iron and Sugarloaf Mountains; (b) the Balaklala Rhyolite roof pendant in the Mule Mountain stock, southeast of Whiskeytown; (c) the Copley Greenstone and Balaklala Rhyolite outside the contact aureole of the gneiss and extending approximately from Boulder Creek southeastward to Monarch Mountain; and (d) the coarsely crystalline actinolite-biotite schist in the extreme southwestern part of the quadrangle.

Only a few of these small drag folds are plotted on the map (pl. 1). Nearly all are in schistose rocks and their plunge is fairly gentle, mostly 10° to 20°, except near the southern end of the pendant of Balaklala Rhyolite where the plunge is as much as 55°. Direction of plunge of drag folds is generally consistent within a given area, but different in different parts of the quadrangle.

Other folds. In addition to the folds described above, S-shaped and arcuate bends are defined by schistosity, especially in the probably synclinal body of the Balaklala Rhyolite that extends through South Fork, Iron, and Sugarloaf Mountains. Except on Sugarloaf, the schistosity in the elongate body of rhyolite strikes generally northeast and dips southeast (pl. 1), but at irregular intervals it bends north for a few tens or hundreds of feet and then resumes its northeast trend. The overall pattern suggests a series of sinistral bends. An example of this type of bend or fold is on Iron Mountain where the largest massive sulfide deposit of the West Shasta copper-zinc district lies in the concave part of the fold. These folds or bends in schistosity probably played a role in the localization of the Iron Mountain deposit, and hence are of economic importance.

A low eastward-trending arch is suggested by the gross outcrop pattern of the Copley Greenstone, Balaklala Rhyolite, and Bragdon Formation in the northwestern part of the quadrangle (pl. 1), and by sparse strikes and dips in the Bragdon. This structure is extremely broad and much disrupted by faults so the crest is hard to define. It probably lies a short distance north of the Brown Bear mine and extends eastward through the window of the Copley Greenstone north of the Washington mine (pl. 2), and thence to the vicinity of Shirttail Peak. The French Gulch fracture zone described below is closely associated with this arch, and both may have formed in response to an upward push by a subjacent salient of the Shasta Bally batholith.

Faults

Faults are abundant in the rocks north and east of the Shasta Bally batholith, but they are rare within and southwest of the batholith, except northwest of Igo in the South Fork mining district (pls. 1 and 2). Two main groups of faults are recognized: (a) the Spring Creek thrust beneath the Bragdon Formation, and (b) high-angle normal faults. The high-angle normal faults served as feeder channels for most of the massive-sulfide and precious-metal deposits of the district, and many of the most important deposits are in veins along these faults. Of somewhat lesser importance are the Spring Creek thrust along which some of the gold deposits occur, and shear zones along which the Ganim gold-talc deposit and possibly some massive-sulfide deposits formed.

Spring Creek thrust. The discordant relation between the Bragdon Formation and underlying rock units at most places in the French Gulch quadrangle is interpreted as being due to a thrust fault called the Spring Creek thrust (Albers, 1964, p. J63). Features indicating a thrust include: (a) the lack of continuity of folds that affect the Bragdon Formation, into rocks underlying the Bragdon, (b) the marked divergence in many places between the attitude of bedding in the Bragdon and the attitude of the underlying contact, (c) the highly contorted shale of the Kennett(?) Formation along the contact in the eastern part of the quadrangle, and (d) the common presence of dikes, quartz veins, and sheared rock along the contact in the western part of the quadrangle. Details of the structural relationship between the Bragdon and underlying rocks are more fully explained in another report (Albers, 1964, p. J62-J64). The Spring Creek thrust is an important structural horizon because many gold deposits in the northern part of the quadrangle occur along it. This is the "pocket" horizon described by Hershey (1910) and by Ferguson (1914, p. 40-43). The thrust is highly irregular and is much disrupted by normal faults. The thrust does not occur everywhere exactly at the lower limit of the Bragdon; locally in the western part of the area it seems to be mainly between the Copley Greenstone and a thin layer of felsic tuff correlated with the Balaklala Rhyolite.

High-angle normal faults. Numerous high-angle faults, most of which show normal movement, cut the rocks north and east of the Shasta Bally batholith (pls. 1 and 2). Faults within and southwest of the batholith seem to be relatively rare or at least obscure except in a few places. The largest normal faults named on the geologic map are: (a) the Hoadley fault, which lies mainly along the northeast side of the Shasta Bally batholith and extends northwestward across the quadrangle, (b) the Shirttail fault, which may in part represent renewed slippage in a normal sense along the Spring Creek thrust, (c) the French Gulch fault which extends through much of the French Gulch-Deadwood mining district, and which may be a continuation of the Shirttail fault. Between the Hoadley fault on the south and the Shirttail and French Gulch faults on the north is a downdropped block, and north of the block is a much faulted structural high shown by the outcrop pattern of the Copley Greenstone (pl. 1). Just south of the crest of this eastward-trending archlike structure is a highly faulted zone marked by numerous dikes and sills of "birdseye" porphyry and quartz porphyry and also by gold-bearing quartz veins of the French Gulch mining district. This highly faulted and intruded zone is herein referred to as the French Gulch fracture zone. An eastward-trending salient from the Shasta Bally batholith is inferred to underlie this fracture zone and the associated archlike structure.

Most of the high-angle normal faults in the quadrangle strike N. 60° to 90° E. and dip steeply, either north or south. Many of these faults are mineralized with gold-bearing quartz, sulfide minerals, or gossan, and as a group they are by far the most important in the quadrangle from an economic standpoint. The Brown Bear, Niagara, American, and Gladstone mines as well as several other gold deposits are in faults of this type, and similar faults were feeder channels for the Iron Mountain and Balaklala massive-sulfide deposits. Displacement on most of these faults is generally a few tens of feet to, rarely, a few hundred feet.

Normal faults, constituting a second prominent group, strike N. 10° to 25° W. and dip at high angles either east or west. Faults in this group are rarely mineralized. These faults are most common in the Bragdon Formation but a few cut the Copley Greenstone, Balaklala Rhyolite, and Mule Mountain stock. Few can be traced with assurance from the Bragdon into underlying rocks, and they are inferred to be cut off by the Spring Creek thrust. The amount of displacement on these faults is not accurately known, but on some it may be as much as 1,000 feet.

High-angle normal faults of a third main group strike N. 45° to 60° W., about parallel to the Hoadley fault, and dip either northeast or southwest. Those that cut the Bragdon Formation are commonly occupied by quartz veins or by porphyry dikes. Displacement on most of these faults is probably small.

High-angle normal faults of a fourth general group strike N. 20° to 45° E. Some, as in the South Fork mining district, are occupied by veins and are therefore of economic importance. Displacement on most of these is probably only a few feet or a few tens of feet.

History of Mining

Placer gold was discovered in the gravels of Clear Creek in the French Gulch quadrangle in March 1848 by Major P. B. Reading who had previously visited the new discovery at Sutter's Mill in El Dorado County. The first production was $60,000 worth of gold taken from the bed of Clear Creek in the fall of 1848 by Major Reading (Ferguson, 1914, p. 33). The discovery of placer gold led to an influx of miners and prospectors, and their activity resulted in the discovery of the Washington lode deposit between French and Scorpion Gulches in 1852. The Washington mine is thus one of the oldest gold mines in the State (Logan, 1926, p. 179). Other early gold mines include the Franklin, discovered in 1852; Mad Mule, discovered in the early 1850's; Niagara, discovered in 1857; Highland (Hightower), discovered in 1869; Gambrinus, discovered in 1870; and Brown Bear, discovered in 1875 (Ferguson, 1914).

Silver was discovered in the southern part of the quadrangle in 1856 (Tucker, 1926, p. 202); the Silver Falls-Chicago Consolidated vein deposit, which was the principal producer in an area known as the South Fork mining district, was located and began to produce in 1866. In 1879 or 1880, silver was discovered in a huge gossan at Iron Mountain by James Sallee (Kett, 1947). This gossan had been discovered in the early sixties by William Magee, a United States land surveyor who, with Charles Camden, held the property as a potential iron mine until Sallee's discovery. The bulk of the silver produced in the quadrangle has come from the Iron Mountain and other massive-sulfide mines.

Copper was already known in Shasta County in the 1850's (Kinkel and others, 1956, p. 76), and was mined in the East Shasta copper-zinc district in the early 1860's (Albers and Robertson, 1961, p. 68). In spite of the interest in copper dating from the 1850's only a few miles east of the French Gulch quadrangle, the existence and importance of copper deposits at Iron Mountain were not recognized until 1894.

Zinc is an important constituent of most of the massive-sulfide deposits but it could not be recovered in the direct smelting process used during the height of mining activity in the district. Consequently, the zinc production is small and does not accurately reflect the content of zinc in the ore. The only zinc produced in the quadrangle was from the Mattie and Richmond Extension ore bodies at Iron Mountain between 1942 and 1947.

Gold mining in the quadrangle was carried on sporadically from the time of the discovery of gold in 1848 until 1942 when World War II resulted in the closing down of virtually all gold mining operations. Little gold mining has been done since 1942. The periods of greatest activity were in the early 1850's soon after the new discovery; from 1900 to 1914, when lode gold mining was stimulated by the needs of the copper smelters for siliceous flux; and during the depression of the 1930's when many unemployed people resorted to mining gold for a livelihood.

The greatest interest in silver mining was from the 1860's to about 1890 when the Silver Falls-Chicago Consolidated mine in the South Fork district operated, and the gossan at Iron Mountain was being worked.

Description of Mines

The precious metal mines of Shasta and Trinity Counties were grouped into rather vaguely defined mining districts in the early days, and four such districts fall within the limits of the French Gulch quadrangle. These are the French Gulch-Deadwood, Muletown, South Fork, and Whiskeytown districts. Although the districts are based principally on geography, the geology of many of the various mines within individual districts has certain similarities. For convenience, the district names are retained in this report and are shown on the generalized geologic map pl. 2).

The Greenhorn mine is the only massive sulfide deposit described herein as comprehensive descriptions of other deposits of this type have been given recently by Kinkel and others (1956).

Precise data on production of gold and silver are lacking but the data given herein, collected from various published and unpublished sources, are believed to be fairly reliable and at least the right order of magnitude for most mines. For convenience all production and assay figures for gold are stated in ounces. The price that prevailed during the period when most of the production was realized was $20.67 per ounce, but since 1933 the price was $35.00 per ounce.

A lack of agreement exists between plans and sections for some of the mines. Owing to the inaccessibility of these mines and uncertainty as to which original drawing—plan or section—is more nearly correct, no attempt has been made to make adjustments.

French Gulch—Deadwood district

In the north-central and northwestern parts of the quadrangle are two gold mining districts, known as the French Gulch district and the Deadwood district. Because of the general similarity of the geology of deposits in both districts, they are combined herein under the name French Gulch-Deadwood district. From them came roughly half the gold production of the quadrangle. The geologic environment suggests that the potential of most of the deposits in this district is not exhausted. Most of the deposits lie along an eastward-trending zone in the Bragdon Formation marked by numerous faults, veins, dikes, and sills. This zone, approximately 9 miles long by 1 to 2 miles wide, is the French Gulch fracture zone. It is on the south flank of a crudely defined eastward-trending arch that is shown mainly by the outcrop pattern of the Copley Greenstone. A subjacent eastward-trending salient from the Shasta Bally batholith is inferred to extend beneath the arch and fracture zone because of the similarity in composition and local similarity in texture of the "birdseye" porphyry dikes and sills along the fracture zone to rocks of the batholith (Albers, 1961, p. C1). Gold deposits occur in veins cutting the Bragdon Formation or in veins cutting the dikes, and also along the Spring Creek thrust between the Copley and Bragdon Formations. Individual deposits are described below.

Accident (Sybil) mine

The Accident mine, also known as the Sybil, is on the south side of the Right Fork of French Gulch. Brown (1916, p. 777) reports that three veins striking N. 80° W. and dipping 50° N. were worked. They have a shale footwall and a "birdseye" porphyry hanging wall. Ferguson (1914, p. 68) states that the ore lies mostly in diorite porphyry near its contact with slate but in places the workings follow the contact itself, which here strikes N. 80° W. and dips 50° NE. However, according to Averill (1933, p. 50), the veins strike northeast and dip nearly vertical, the best ore being where shale forms the hanging wall. The veins apparently were worked through a vertical distance of 350 feet below the outcrop by means of a series of closely spaced levels and a winze 150 feet deep from the lowest level. A rich ore shoot 90 feet long is stated to have been stoped from this shaft (Averill, 1933, p. 50). The ore is quartz containing pyrite, sphalerite, galena, arsenopyrite, and free gold.

The position of this deposit in shale and porphyry several hundred feet above the Copley Greenstone contact and virtually on the crest of the eastward-trending arch is thought to be favorable to mineralization, and further prospecting might reveal additional ore shoots at depth along and above the greenstone contact.

American mine

The American mine, sometimes called the Old American, is in the prominent ridge between Clear Creek and JIC Gulch. Ferguson (1914, p. 60) states that the deposit was discovered in 1887 and that the surface ores were rich. Production to 1914 was estimated to be about 14,300 ounces of gold (Brown, 1916, p. 778).

The gold is in a quartz vein that strikes N. 80° E. and dips steeply south. The vein ranges from a fraction of an inch to about 3 feet thick and cuts the upper unit of the Bragdon Formation (pl. 1), which, in the mine area, consists of shale and conglomerate in roughly equal proportions. These enclosing rocks

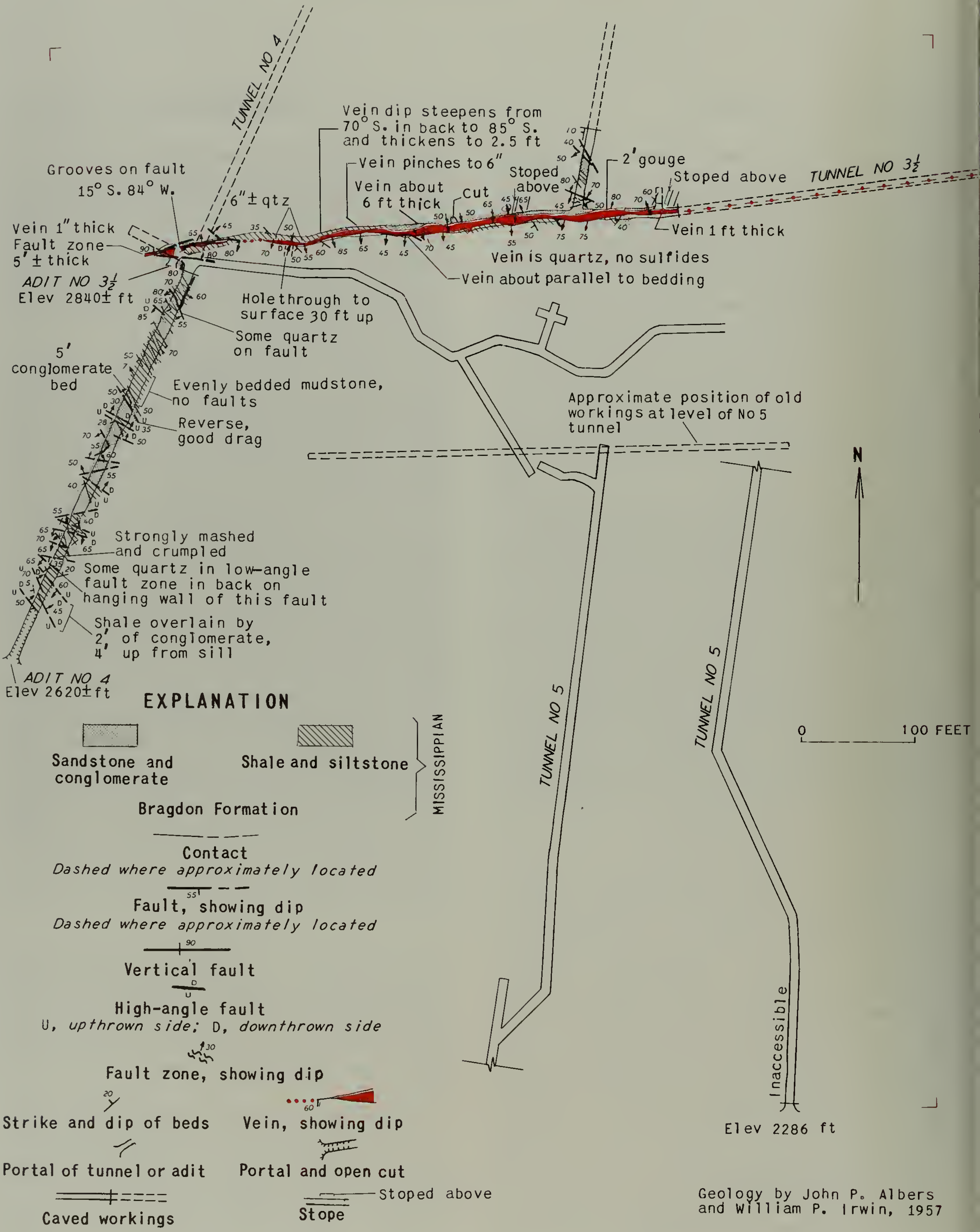

TUNNEL NO 4
Vein dip steepens from 70° S. in back to 85° S. and thickens to 2.5 ft
Vein pinches to 6"
2' gouge
Stoped above
Stoped above
TUNNEL NO 3½
Grooves on fault 15° S. 84° W.
6" ± qtz
Vein about 6 ft thick
Cut
Vein 1" thick
Fault zone 5' ± thick
Vein 1 ft thick
Vein is quartz, no sulfides
ADIT NO 3½
Elev 2840± ft
Vein about parallel to bedding
Hole through to surface 30 ft up
Some quartz on fault
5' conglomerate bed
Evenly bedded mudstone, no faults
Reverse, good drag
Approximate position of old workings at level of No 5 tunnel
N
Strongly mashed and crumpled
Some quartz in low-angle fault zone in back on hanging wall of this fault
Shale overlain by 2' of conglomerate, 4' up from sill
ADIT NO 4
Elev 2620± ft
TUNNEL NO 5
TUNNEL NO 5
0 100 FEET
Inaccessible
Elev 2286 ft
EXPLANATION
Sandstone and conglomerate
Shale and siltstone
Bragdon Formation
MISSISSIPPIAN
Contact
Dashed where approximately located
55
Fault, showing dip
Dashed where approximately located
90
Vertical fault
D
U
High-angle fault
U, upthrown side; D, downthrown side
30
Fault zone, showing dip
20
Strike and dip of beds
60
Vein, showing dip
Portal of tunnel or adit
Portal and open cut
Caved workings
Stoped above
Stope
Geology by John P. Albers and William P. Irwin, 1957

Figure 2. Map of the American mine, Shasta County, California.

are in general much faulted and broken. A short distance north of the mine is the Shirttail fault. No porphyry was seen in the mine area. The vein was worked at intervals through a vertical distance of 700 to 800 feet from three principal levels and numerous pits and shallow openings. The lowest level, the No. 5 tunnel at altitude 2,286 feet, is about 800 feet below the outcrop (fig. 2). It was inaccessible in 1957, but according to Averill (1939, p. 130) it extends 1,150 feet north from the portal where it intersects the vein. From this point of intersection a drift extends 150 feet east and 270 feet west, and at 60 feet west a winze 110 feet deep was sunk on the vein. The No. 3½ and No. 4 adits, at altitudes 2,840 and 2,620 feet respectively, were partly accessible in 1957. The geology of accessible workings is shown on figure 2.

The ore consists of white to bluish-gray quartz containing minor pyrite, galena, and arsenopyrite, as well as native gold. All these minerals are spatially related to shale wall rock or to shale inclusions in the quartz vein. Ferguson (1914, p. 61) reports seeing gold in small plates and imperfect crystals close to the contact of quartz and shale and in dark bands in the quartz.

The rake of the American ore shoot could not be determined during the present study. L. A. Woodworth, mining engineer, who made a private study of the Gladstone area in 1935, believes that the ore shoot rakes steeply eastward towards the JIC shoot. The vein may continue in depth to the Copley Greenstone contact which in this locality should be the eastward-dipping Shirttail fault.

Brown Bear mine

The Brown Bear, the largest gold mine in the French Gulch quadrangle, is about a mile from the western edge of the quadrangle, near the west end of the French Gulch-Deadwood district. A dirt road maintained by the county gives access to the property. The mine was closed and workings were inaccessible at the time of the present study (1956-1957), and much of the following description is from Ferguson (1914, p. 70-71), Averill (1933, p. 13-15), and from unpublished data kindly supplied by E. E. Erich, geologist and owner of the mine. The underground maps and sections have likewise been supplied by Mr. Erich.

The deposit was discovered about 1875 and extensive mining operations were begun in 1876. Several additional discoveries were made in 1876 and succeeding years, and the present Brown Bear mine is a consolidation of all these discoveries. Production is estimated from fragmentary data to range from 400,000 to 500,000 ounces of gold. The mine is developed over a vertical distance of about 1,000 feet and a strike length of 3,500 feet by about 11 miles of drifts and crosscuts and by numerous stopes. The Watt tunnel, about 6,000 feet long, is the main haulage level, and it drains and ventilates the entire mine. It opens near the north bank of Deadwood Creek at an altitude of about 2,735 feet and extends beneath the upper levels. Other principal levels include: the China level, altitude 3,089; the Roberts level, altitude 3,176; and the Monte Cristo level, altitude 3,340.

Most of the gold has come from two veins, the Monte Cristo and Last Chance. These veins are parallel and about 200 feet apart. They have been explored for about 2,600 feet along their strikes and were mined to depths as much as 760 feet below the surface. In addition, several small veins worked mainly near the surface have yielded high-grade ore. Ferguson (1914, p. 71) reports that the general run of stoped ore yielded about 1 to 2½ ounces of gold per ton and that the best ore yielded nearly 5 ounces per ton. The gold is about 840 fine.

The ore consists mainly of quartz that contains free gold and varying amounts of pyrite, galena, sphalerite, and arsenopyrite. Pyrite is the most common sulfide in the ore and also in the adjoining country rock. Arsenopyrite is reported by Ferguson (1914, p. 71) to be almost exclusively confined to altered porphyry. Galena and sphalerite are rarely found outside the veins and their presence generally indicates rich ore. Some silver is present, probably in the galena. Calcite is reported to be comparatively rare in the ore but common as veinlets in the porphyry and slate near the veins. Manganese oxide is common in the veins near the surface.

The Brown Bear mine is in the lower unit of the Bragdon Formation near the western end of the French Gulch fracture zone. The shale and siltstone of the Bragdon are cut by numerous anastomosing dikes of both "birdseye" porphyry and quartz porphyry that strike approximately east and dip steeply, north or south. Quartz veins that also strike east, and dip steeply, cut the Bragdon Formation and also cut the porphyry dikes. The veins are fissure fillings that pinch and swell abruptly along strike and down dip. Information supplied by E. E. Erich shows that the veins range in thickness from a thin seam to as much as 22 feet. In places vein material is absent and the fissure is marked only by a few inches of gouge. Gouge ranging from a fraction of an inch to about 2 feet thick, and commonly containing fragments of quartz and small amounts of gold, is present along the contacts of most porphyry dikes and also along most veins, indicating that post-mineral movement has occurred.

Studies of the mine by E. E. Erich show that the most strongly mineralized zones occur where numerous veins and fractures intersect. This is evident particularly where the two main veins, Monte Cristo and Last Chance, are intersected by more or less parallel veins of opposite dip. A resulting abundance of small ore shoots formed by intersecting parallel veins are thus nearly horizontal and where taken together form horizontal mineralized zones. This pattern is indicated by the distribution of stoped areas shown on the longitudinal projection (pl. 3). On the Monte Cristo vein an upper mineralized zone lies almost entirely above the Monte Cristo level, and a lower zone, not much explored, is suggested by the rather abrupt widening of a stope below the China level. On the Last Chance vein two horizontal zones, an upper zone above the Roberts tunnel corresponding to the upper Monte Cristo, and a lower zone starting above 150 feet below this tunnel, are clearly indicated.

Information furnished by E. E. Erich indicates that gold in the upper zones of both the Monte Cristo and Last Chance veins diminishes with depth and virtually disappears at depths around 400 feet below the surface. The two main veins continue below this depth but carry little or no gold down to about 600 feet where gold again reappears only to diminish again at about 750 feet although the quartz veins continue. It is postulated by Erich that a third zone of intersecting veins and consequently a third mineralized zone, begins at 50 to 100 feet below the Watt tunnel.

The concentration of gold at vein intersections was apparently recognized early in mining at the Brown Bear. However, according to E. E. Erich, much needless exploration of barren local vein intersections was done before it was realized that gold concentrations occurred only where vein intersections were within one of the main mineralized zones.

Inasmuch as the deposits mined are entirely within the Bragdon Formation and in dikes that cut the Bragdon, it is possible that a mineralized zone exists beneath present workings, just above the Copley Greenstone contact. This contact is strongly mineralized elsewhere along the French Gulch fracture zone, as at the Washington and Milkmaid mines, and there is no reason to suppose that it should not be similarly mineralized where the main Brown Bear veins intersect the contact between highly contrasting rock types. This contact is likely to be marked by a sill-like body of "birdseye" porphyry and is probably not more than 400 feet below the Watt tunnel level.

Brunswick mine

The Brunswick mine, also called the Miners' Group of Mines, at an altitude of about 3,900 feet near the crest of a high ridge between Sawpit and Summit Gulches (pl. 2), was located in 1879 (Ferguson, 1914, p. 68). Production to 1912 was about 3,700 ounces of gold. There is no record of production since then, although considerable work at the property was done during the 1930's by Rossi and Rossi of French Gulch (Averill, 1939, p. 143). All mine workings were inaccessible in 1957 and no maps could be found. Mrs. Frank Rossi of Roseville, California, owned the property at that time.

In the Brunswick mine area the upper unit of the Bragdon Formation is cut by an augite-bearing dike of "birdseye" porphyry that strikes about N. 80° W. According to Ferguson (1914, p. 68), the gold mined in 1912 and earlier years was entirely within the porphyry at a distance of 1 to 10 feet from its northern contact and consisted of small lenses of quartz and subordinate calcite in a narrow crushed zone. Averill (1939, p. 143) states that work done during the late 1930's was on a quartz vein about 1 foot thick, the hanging wall of which is slate and the foot wall porphyry. Country rock for several feet on either side of the vein reportedly was strongly mineralized and mineable as commercial ore. Ferguson (1914, p. 68) indicates that the only sulfide mineral present is pyrite, but that the quartz is stained and streaked with iron oxide and manganese oxide. The best ore reportedly ran about half an ounce per ton.

Calmich mine

This mine is on Thorne Gulch about a mile southeast of the Brown Bear mine. Rocks in the area are gently dipping, slightly deformed shale and siltstone of the Bragdon Formation. No porphyry crops out in the immediate area. Averill (1933, p. 17) states that the mine is on a vein that strikes nearly east and dips north. However, the distribution of adits suggests a vein striking about N. 45° W. and dipping 40° NE. The vein averaged 6 inches thick and had a maximum thickness of 10 inches (Averill, 1933, p. 17). The ore shoot was 90 feet long, raked east, and reportedly yielded nearly 3 ounces of gold per ton. A second irregular ore shoot 30 feet long was also mined.

Centennial mine

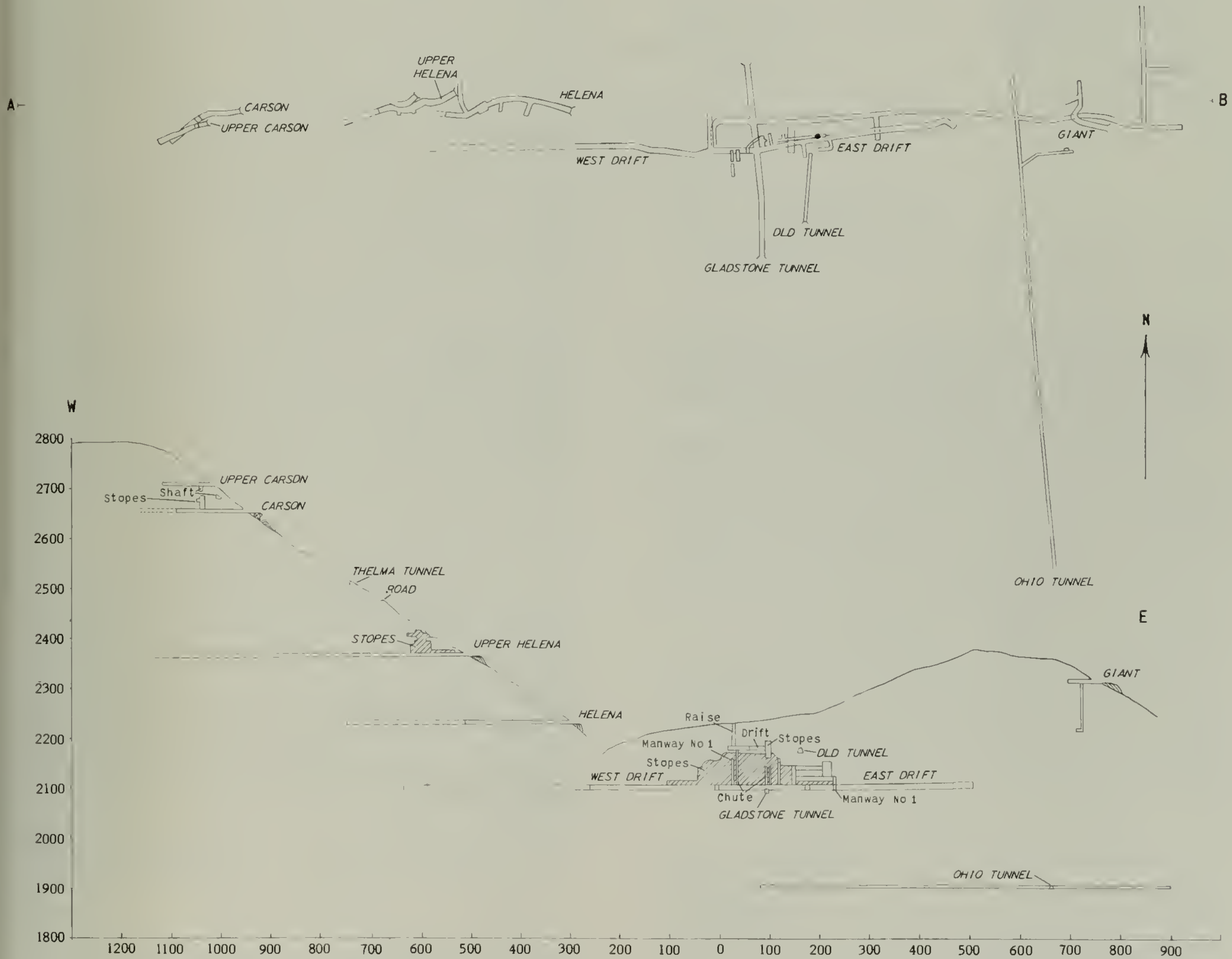
This mine, located in Centennial Gulch north of Right Fork of French Gulch, was discovered in 1876 according to information collected by O. H. Hershey in 1927 and furnished the writer by E. M. Clark. Iron-stained oxidized ore was extracted from an open cut 140 feet long by 6 feet wide, and primary ore was mined to a depth of 120 feet from a series of adits. The ore occurred in a vein that strikes N. 60° E. The ore shoot reportedly averaged 3 feet thick and yielded nearly 4 ounces of gold per ton.

Gladstone mine

The most easterly and the second largest mine in the French Gulch-Deadwood district is the Gladstone. It was discovered in 1887 and was a steady producer from 1901 to 1916. It is owned by the Hazel Gold Mining Company. Total production through 1916 was about 206,765 ounces of gold. Available data indicate that little gold has been produced since 1916, and virtually no work has been done on the property since 1924. I am indebted to Clayton T. McNeil of San Francisco, who supplied much of the data used in this description.

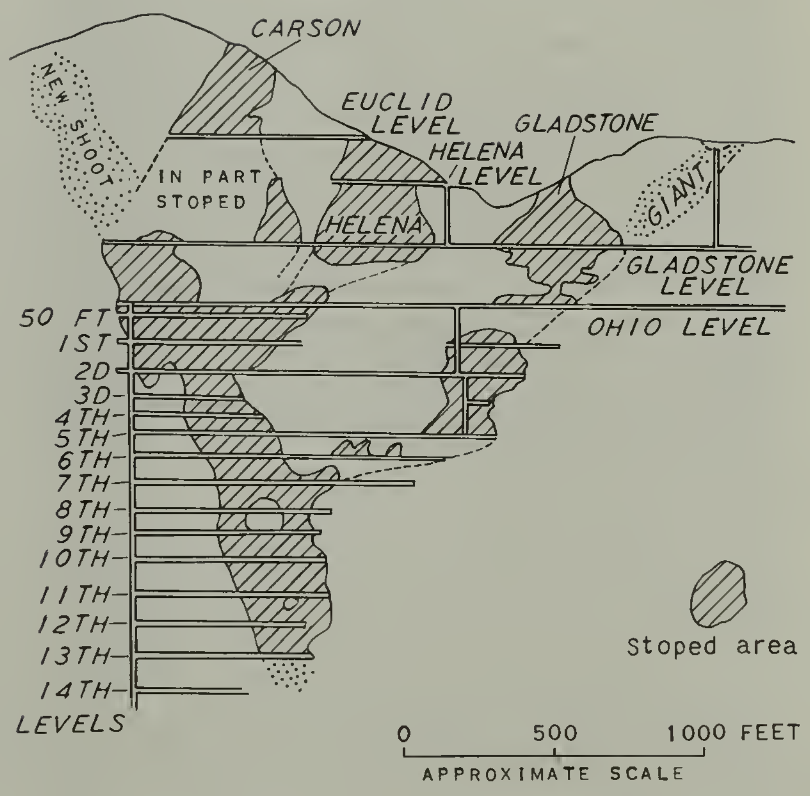
A quartz vein that strikes nearly east and dips from about 60° S. to nearly vertical is in a 50- to 70-foot-thick crushed zone in shale, conglomerate, and sandstone of the upper unit of the Bragdon Formation. No porphyry is associated with the vein, although a small body of porphyry was found in the mine about 150 feet from the vein. The vein ranges from about an inch to 12 feet in thickness, and the average thickness of stoped portions was about 2½ feet (Ferguson, 1914, p. 58). Stoping was done on three different ore shoots, including the Carson on the west, Helena in the middle, and Gladstone or Giant on the east (fig. 3), over a total strike length of 2,000 feet and to a depth of 2,000 feet below the outcrop. As indicated by the longitudinal projection (fig. 4), the three shoots rake steeply west in the upper part of the mine, but apparently merge between the first and seventh levels and rake steeply east in the deeper levels. The longitudinal projection (fig. 4) indicates that the shoot was stoped to the thirteenth level and that it probably continues, though narrower, to the fourteenth level. The nearly straight western edge of the east-raking ore shoot suggests a fault, which possibly may be the large north-trending fault shown on plates 1 and 2.

The vein material is mainly quartz with subordinate calcite as grains 1 to 2 cm in diameter, and free gold, pyrite, galena, sphalerite, and arsenopyrite (Ferguson, 1914, p. 59). Pyrite is the most abundant sulfide and commonly occurs as small crystals closely associated with shale wall rock or shale inclusions in the vein.



Copied from old section furnished by John MacGuinnis, lessee, Gladstone Mine, July, 1957. Published with owner's permission

Figure 3. Map and longitudinal projection of upper workings, Gladstone mine, Shasta County, California.



By L. A. Woodworth, E. M., 1935.
Published with owner's permission

Figure 4. Longitudinal projection of the Gladstone mine, Shasta County, California.

The other sulfides are rare and occur only within the vein. Visible gold was apparently less common than in other mines of the region but many small specks were seen near shale inclusions and wall rock.

The average grade of 339,200 tons of ore mined over the 15-year period of 1901-1916 was a little less than half an ounce of gold per ton. However, the best ore ran as high as 4 ounces per ton. Ferguson (1914, p. 59) reports that an oxide zone extended to a depth of 75 feet and that the grade of ore in this zone was irregular, in contrast to the more even tenor of the ore below the oxidized zone.

Prospects for finding additional ore at depth in the Gladstone appear good as the lowest of the old workings should be at least several hundred feet above the Copley Greenstone contact. The vein system probably continues down to that contact, which itself should be a favorable zone.

Henry Clay mine

In September 1929, Mr. H. F. Byram, a mining engineer, accompanied by a local resident, visited the Henry Clay mine, which adjoins the Brown Bear mine on the north. The Henry Clay comprised possibly three claims, all patented. At that time this property was credited with a production of from $100,000 to $300,000 (4,840 to 14,520 oz.) in gold. The course of the vein in an upper tunnel was N. 60° E., magnetic. The entire production apparently came from a very small area, pipe-like in shape. In 1929 the workings were open but the old stope about 270 feet in from portal was enlarged by caving into a large high-ceiling room and the vein could not be reached or examined.

Highland (Hightower) mine

This mine, east of the head of Dutch Gulch, was discovered before 1869 (Ferguson, 1914, p. 69) and is said to have produced several hundred thousand dollars in the years prior to 1885 (Averill, 1939, p. 139). The property is marked by numerous pits and short adits on the south side of Highland Ridge. Extensive underground workings reportedly exist on the property, including one adit 1,800 feet long (Brown, 1916, p. 789, and Averill, 1939, p. 139). These could not be located in 1956-1957.

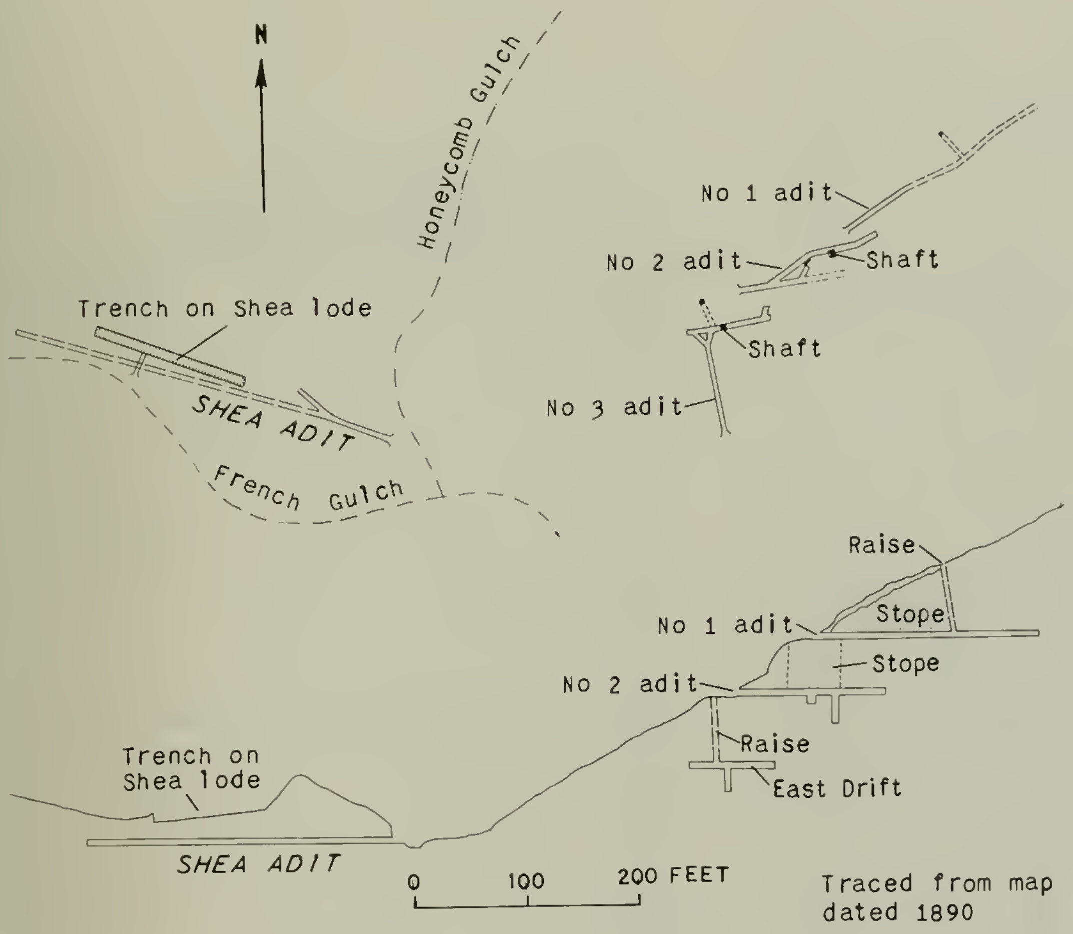
The country rock is the lower shaly unit of the Bragdon Formation cut by a few small dikes of "birdseye" porphyry; the vein material is quartz. Brown (1916, p. 789) states that the vein strikes north and dips 20° E., but according to Averill (1939, p. 139) it strikes east and dips 40° S. Averill also notes that the vein lies parallel to the hillslope. The lack of agreement between Brown and Averill on the attitude of the vein could possibly mean that two veins about at right angles have been worked at the Highland mine. On the other hand, our observations in 1956-1957 indicate that virtually the entire hillside area where the diggings are located is landslide debris, as shown on the geologic map (pl. 1). No solid outcrop of the Bragdon Formation was seen in the area of the diggings, and the vein material is likewise merely dislocated pieces. It therefore seems likely that a goodly percentage of the material mined in the early days was fragmented vein material derived from a vein now largely, if not entirely covered by the landslide. In this case the vein or veins would be north of, or on the hanging wall side of the large east-trending fault shown on the geologic map.

Honeycomb and Shea mines

These mines are near the junction of French and Centennial Gulches. The Honeycomb vein strikes N. 50° E. and dips about 45° SE. Most of the Honeycomb workings are in the Copley Greenstone, but the largest stopes seem to be near the contact between greenstone and the Bragdon Formation. The deposit is supposed to have yielded some fairly good ore, probably from the contact zone between shale and greenstone.

The Shea deposit, across Centennial Gulch from the Honeycomb, is also on the contact between shale and greenstone. Observations by O. H. Hershey in 1927 indicate that the Shea ore shoot, which yielded good ore, raked west at a very low angle along the contact. A tunnel driven on a steeply dipping quartz vein in greenstone below this contact encountered little ore.

Figure 5 is a map and longitudinal projection of the Honeycomb and Shea mines made in 1890 and graciously made available by E. M. Clark.



Traced from map dated 1890

Figure 5. Plan and longitudinal projection of the Honeycomb and Shea mines, Shasta County, California.

JIC prospect

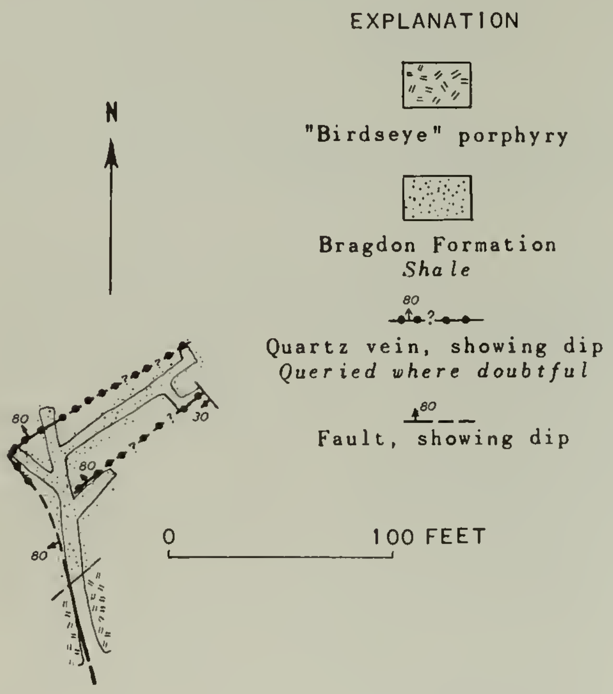
This prospect, called the Jay Eye See mine by Crawford (1894, p. 250-251), is west of JIC Gulch. It is midway between the American and Gladstone mines, and apparently on the same east-trending fracture zone, but is separated from the two mines by north-trending faults.

According to Crawford (1894, p. 250-251), the quartz vein strikes N. 63° W., dips 60° to 75° N., and ranges in thickness from 8 inches to 4 feet. Workings in 1894 included three crosscuts totaling at least 700 feet, drifts totaling about 420 feet, a shaft 38 feet deep, and a winze 90 feet deep. Exploration was to a depth of 236 feet. Brown (1916, p. 790) reports that workings then consisted of a tunnel 1,000 feet long, 300 feet of drifts, and 220 feet of inclined shaft. High-grade ore was reportedly taken from the JIC mine but no records of production are known. Notes by Lawrence A. Woodworth, mining engineer, who examined the property in 1935, suggest that the ore shoot may rake steeply west. The workings were inaccessible in 1957.

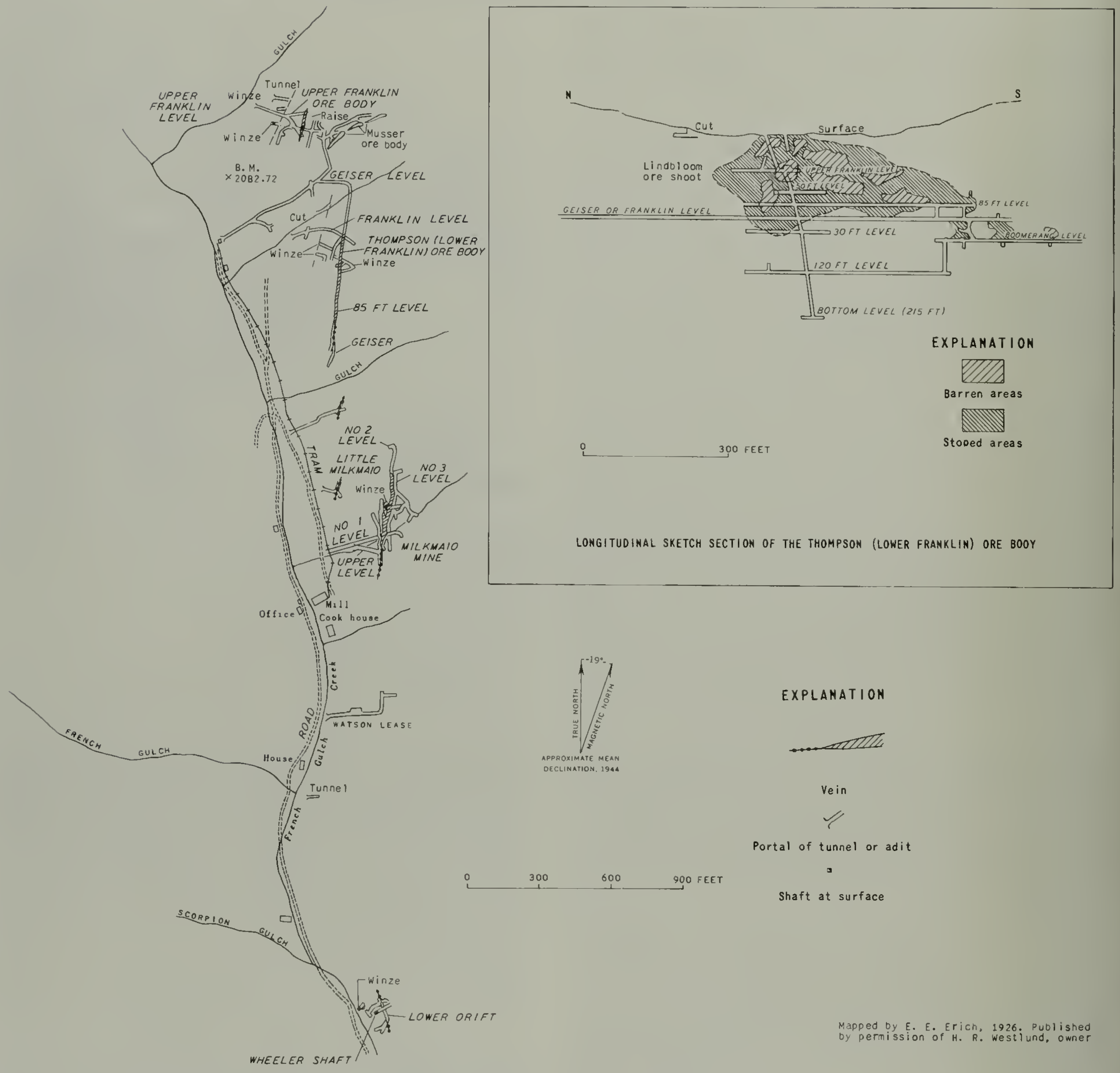
Ike Wertz prospect

This prospect, owned by E. M. Clark, is south of Right Fork French Gulch, about midway between the Washington and Scorpion mines. Two quartz veins, approximately parallel and about 50 feet apart, strike N. 55° E. and dip 80° NW. in shale of the Bragdon Formation. A third vein striking N. 10° to 20° W. and dipping 80° SW. intersects the more northerly of the other two. In 1957 the veins had been exploited at three levels by about 450 feet of workings. Figure 6 is a sketch of the lowest level. Ike Wertz, lessee, stated that parts of the veins had yielded high grade ore.

Figure 6. Sketch of the lowest level of the Ike Wertz prospect, Shasta County, California.



J. P. Albers, 1957



Mapped by E. E. Erich, 1926. Published by permission of H. R. Westlund, owner

Figure 7. Map and sections of the Milkmaid and Franklin mines, Shasta County, California.

Larry mine

Near the extreme western edge of the map and a short distance northwest of the Brown Bear mine is a group of adits in shale cut by "birdseye" porphyry dikes. A sign seen on the property in 1956 indicates that these workings are known as the Larry mine, owned or leased by I. W. McConnell. Apparently no work had been done on the property for several years prior to 1956. The adits seem to be driven on different structures, the most prominent of which is a fault zone striking N. 45° W. and dipping about 60° SW. in the lower unit of the Bragdon Formation.

Averill (1941, p. 45) refers to this property as the Larry mine owned by E. L. McConnell and others of Castella, California. According to Averill (1941, p. 45), some of the workings in this locality belong to the Henry Clay mine which evidently has produced some gold from a quartz vein 4 feet thick.

Milkmaid and Franklin mines

These adjoining mines are at the east end of a window of Copley Greenstone on the east side of French Gulch at an altitude of about 2,000 feet (pl. 2). Both mines were discovered in the early 1850's and are among the oldest in the State. According to information supplied by E. E. Erich, who studied the geology of the two mines during 1925-1926, between 48,500 and 71,400 ounces of gold were produced, more than half of it prior to 1907 when records were incomplete.

Production data supplied by E. E. Erich indicate that about 24,300 ounces of gold were mined from 1907 to 1925. Production since 1925 is not known.

The ore deposits are associated with a sill of quartz porphyry between the Copley Greenstone and the Bragdon Formation, the deposits lying chiefly along the east-dipping contact between the porphyry and shale of the Bragdon Formation. The porphyry probably was intruded along the Spring Creek thrust between the Copley and Bragdon formations. The mineralized contact zone strikes nearly north and has been traced for about 4,000 feet. If projected westward updip across French Gulch, this contact would coincide with the contact between shale and the underlying porphyry and greenstone at the Washington mine. The outcrop of the mineralized zone, at an altitude of about 2,100 feet, is marked by numerous pits and trenches. According to information supplied by E. E. Erich, the gold occurs in lenticular bodies of quartz, the largest of which is about 500 feet long, 4 to 10 feet thick, and extends downdip about 200 feet. The average gold content of these lenses was reportedly about 2 ounces per ton. The ore bodies of this type include, from south to north (fig. 7), Wheeler, Milkmaid, Thomson, and Upper Franklin. A cross section supplied by E. E. Erich and believed to be typical of these ore bodies is also shown on figure 7. Gold was also found along the margins of these bodies in small quartz stringers as much as 10 feet long and 1 foot thick; these stringers strike nearly east at right angles to the strike of the contact and of the main ore bodies. In places the stringers were closely spaced and high enough in grade to make mining of as much as 10 feet of the wall rock profitable. Ferguson (1914, p. 63) reports that the ore shoots are irregular in shape and rake steeply to the south. This is not obvious from existing maps and sections, which suggest a nearly horizontal rake or at most a very gentle rake to the south (fig. 7).

The vein material is predominantly quartz containing subordinate calcite, and free gold, pyrite, galena, and sphalerite. A small amount of silver in the ore and, rarely, gold telluride, is reported by E. E. Erich. The silver probably was contained in galena. Telluride has not been recognized elsewhere in the district. Outcrops of the vein are commonly partly oxidized and leached to depths of 10 or 20 feet, but in a few places along cracks the oxidation extends to as much as 100 feet. Erich reports that some of the ore in upper parts of ore bodies along the contact between shale and porphyry was residually enriched by the oxidation and leaching of some of the minerals. However, except for a few feet below the outcrop, most ore was unoxidized and unenriched by supergene processes.

In addition to the ore bodies along the contact between shale and quartz porphyry, a vein in the porphyry, striking about N. 70° E. and dipping 70° N., was worked in the Franklin mine. The ore body, known as the Musser, yielded about 2,000 ounces of gold, according to data supplied by E. E. Erich. The vein reportedly extended upward to the overlying shale contact. The intersection of this vein with the contact between porphyry and shale should be a favorable area for additional prospecting as this contact has been so productive elsewhere in the Franklin-Milkmaid area. As may be seen on plate 2, the Musser vein has the same attitude and is directly along strike of the most prominent vein in the Washington mine. The two veins probably connect but they could not be traced across the intervening gulch.

Ferguson's (1914, p. 63) description of the ore in the Franklin mine indicates that arsenopyrite was also present in addition to the other sulfides mentioned above. It occurs as scattered crystals in altered porphyry along vein walls and in small quartz stringers, but apparently does not occur in the main vein. According to Ferguson (1914, p. 63), sulfides accounted for about 0.75 percent of the weight of the ore and carried about 7 ounces in gold per ton. Visible gold was also fairly prominent in this ore and is most commonly found in close association with galena.

The mineralized zone along the contact between shale and prophyry probably continues in depth, flattening eastward towards the Three Sisters mine. This area is therefore considered favorable for further prospecting under favorable economic conditions.

Niagara mine

The Niagara mine is in the western part of a prominent ridge between French and Scorpion Gulches. The mine was discovered in 1857 (Ferguson, 1914, p. 66), and total production is estimated at about 50,000 ounces of gold. Mr. E. M. Clark, owner of the property, has kindly furnished maps and other information collected by O. H. Hershey, J. A. Kruse, and A. W. Johnson during a period when the mine was accessible.

The principal vein, called the Niagara, strikes N. 70° E. and dips at average angles of 70° to 75° SE. It is developed through a vertical distance of 500 feet by several thousand feet of workings at 10 levels, the lowest of which is the O'Neal tunnel at an altitude of 2,943 feet (pl. 4). In addition to these levels, the Barnes level starting just above French Gulch at an altitude of 2,400 feet, extends beneath the entire mine area. The vein consists of quartz with minor calcite (Ferguson, 1914, p. 66). It rakes at an angle of about 40° SW. Old maps indicate that it cuts "birdseye" porphyry or quartz porphyry in some places, shale in places, and in still others is along the contact between porphyry and shale. Ferguson (1914, p. 66-67) states that pyrite, galena, sphalerite, and arsenopyrite are present in small amounts. Pyrite is the most widely distributed, being found in the vein quartz, in small stringers in shale, and disseminated in porphyry. It is also closely associated with galena and in places surrounds grains of galena. Arsenopyrite is most commonly disseminated in the altered porphyry wall rock, and galena and sphalerite are most abundant near the shale wall rock and near shale fragments in the vein.

As shown on the longitudinal projection, the Niagara ore shoot was about 1,100 feet westward down the rake from the outcrop. At about 800 feet from the outcrop it was displaced downward about 100 feet by a fault striking N. 35° W. and dipping about 70° SW. This fault was also mapped by A. W. Johnson on the Barnes level about 540 feet lower, and it probably coincides with the French Gulch fault mapped on the surface (pl. 2). Unpublished data supplied by E. M. Clark indicate that the Barnes tunnel was driven in an attempt to intersect and exploit the downfaulted segment of the Niagara vein at a lower level. Assuming that the vein continues below the O'Neal level, that its dip remains constant at about 75° SE., and that the rake of the ore shoot remains southwestward at an average angle of 35° to 40°, the projected extension of the vein at the altitude of the Barnes level should be about 100 to 125 feet east of the extreme southwestern end of the Barnes level workings as shown on figure 11. The projected vein should extend about 220 feet eastward from there where the ore shoot would rise at the angle of rake above the Barnes level. However, if the rake becomes more gentle, as is vaguely suggested by the stope outline west of the French Gulch fault on the O'Neal level, the projected extension of the ore shoot at the Barnes level would obviously be farther west, the distance depending on the angle of rake.

Available data suggest that favorable prospecting ground still remains in the southwestern part of the Niagara mine below the O'Neal level. The vein system may extend southwestward and intersect the Scorpion-Montezuma vein system in the vicinity of the Niagara Summit portal, but exposures are too poor in the intervening area to be certain.

Niagara Summit mine

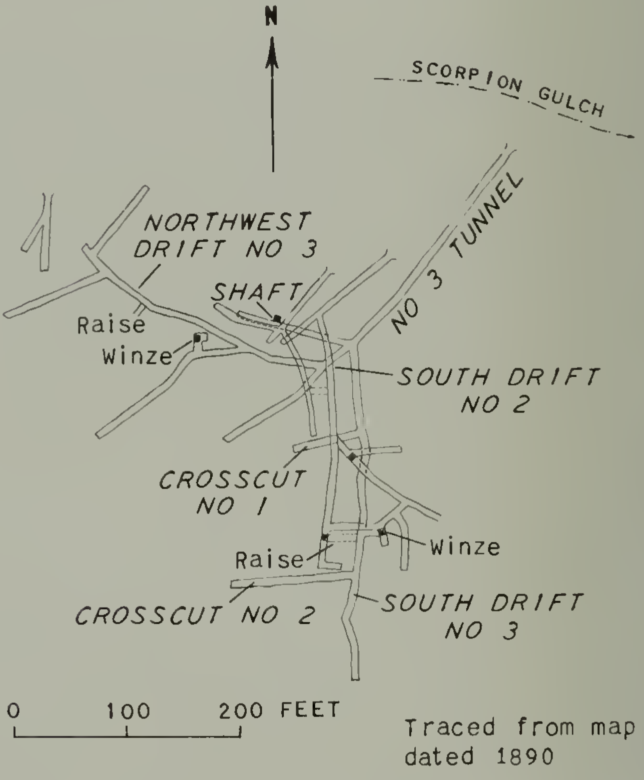
This mine is just east of the main divide between Shasta and Trinity Counties. It is in the lower unit of the Bragdon Formation, on the same fracture system as the Vermont and Montezuma mines, and probably on the same system as the Scorpion. As may be seen on plate 9, the main adit of the Niagara Summit extends nearly to the Montezuma workings. The workings were inaccessible during 1956-1957, and no detailed information on the geology of the deposit is available.

Philadelphia mine

This mine, south of the Niagara and on the north side of Scorpion Gulch, is a shallow deposit in an oxide zone. Averill (1933, p. 43) reports that lenses of high-grade oxidized ore were contained in soft decomposed diorite ("birdseye") prophyry. The lenses ranged from a few inches to about 4 feet thick and each lens yielded 15 to 30 tons of ore that reportedly contained about 6 ounces per ton in gold. The ore is described by Averill (1933, p. 44) as soft, yellowish and reddish brown, with some black probably due to manganese. The prophyry in which the ore occurs is underlain by gently dipping shale.

Scarpion mine

The Scorpion mine, near the head of Scorpion Gulch, was discovered prior to 1890 and the last work of which there is any record was done around 1910. Production is reportedly about 7,140 ounces of gold. A brief description of the mine made in 1927 by O. H. Hershey has been furnished by E. M. Clark, the owner. The vein on which the mine was developed is along a fault in highly sheared and mashed black shale of the Bragdon Formation. The fault, which strikes N. 50° W. and dips about 70° SW., probably continues for nearly a mile northwest to the Montezuma mine. At least three lenticular masses of quartz porphyry occur along the footwall of the fault (pl. 2). The vein is discontinuous and is mainly in the sheared shale but partly in the porphyry. Hershey's data indicate that various blocks of ore having an aggregate length of 90 to 140 feet and a depth of 150 feet to the No. 3 tunnel (fig. 8) were stoped. In 1910 a winze was sunk to a depth of 105 feet below the No. 3 level and reportedly encountered an 18- to 20-inch-thick vein of very rich galena containing gold particles as large as wheat grains. The vein was in porphyry, and Hershey's interpretation was that a rich pocket or chimney of ore had been located. Legal complications apparently caused the mine to be closed before this pocket could be mined and the winze was subsequently flooded. Hershey's description indicates that the ore found in the winze was not mined up



Traced from map dated 1890

Figure 8. Map of the Scarpion mine, Shasta County, California.

to 1927, but no information is available on whether it was worked since 1927.

Summit mine

The Summit mine is at an altitude of 3,250 feet, on the south side of a prominent ridge, about a mile east of the Trinity County line. It was discovered prior to 1907 and in 1957 was owned by Mrs. Marian G. Fondahn of French Gulch. The mine has been inactive since the 1940's except for work by a lessee, Don Carlson of French Gulch. Mr. Carlson kindly guided the writer through accessible parts of the mine and provided a plan and longitudinal section of the workings (pl. 5). Production to 1912 is estimated to be about 9,850 ounces of gold (Ferguson, 1914, p. 67). No data on production since 1912 are available, but considerable work has been done.

The mine lies about a mile south of the main east-trending French Gulch fracture zone. It is in the upper unit of the Bragdon Formation, which, in the mine area, is cut by three small dikes of "birdseye" porphyry. The gold is in a series of quartz veins mostly a few inches to 2 feet thick whose strikes range from north to N. 25° E. The principal vein, called the Brown, dips at angles of 40° to 65° E. The vein system is cut off in the western part of the mine by a fault (called a header by local miners) striking N. 30° W. and dipping 50° SW.

From observations made on the Galena level and on parts of the Barnes level in 1957, it seems clear that the most important ore shoots are localized at the intersection of veins with opposing dips. The best example of this is the stope at the northeast end of the Galena level where the eastward-dipping Brown vein is joined by a vein that dips west. The apex formed by the intersecting veins is well exposed about 10 feet above the level and plunges northeastward at approximately 28°. An underhand stope extends below the Galena level on this plunge. Other concentrations of gold were found at bends and irregularities at the contact between veins and black carbonaceous shale. Ferguson (1914, p. 67) reports that the vein quartz is vuggy and that gold is present both on and within some of the quartz crystals. Sphalerite, galena, pyrite, and arsenopyrite are sulfides associated with the gold. Like the gold, they occur mostly near the walls of veins.

Future work at the Summit mine should be in areas where vein intersections might occur. The Brown vein probably continues for several hundred feet beneath the Barnes level, and small ore shoots of the type found above the level may be expected at irregular intervals.

Three Sisters mine

This mine is in the bottom of Dutch Gulch at an altitude of about 1,850 feet. It was discovered in 1895 (Crawford, 1896, p. 367), and by 1913 the workings consisted of a tunnel 1,350 feet long, 800 feet of drifts, a stope 200 feet long, and a winze 120 feet deep (Brown, 1916, p. 800). The mine produced between 1895 and 1905, but records of production and maps are not available.

Surface observations made during the present study indicate that adits driven on both the east and west sides of the gulch follow a 3-foot-thick fault zone that strikes N. 50° E. and dips 70° NW. Vein material consists of ribbons and lenses of milky bull quartz and some calcite in sheared and broken quartz porphyry. Tension fractures indicate that the hanging wall block on the fault is downdropped. The quartz porphyry dike is in the lower unit of the Bragdon Formation. Disseminated crystals of arsenopyrite and pyrite were seen in vein material on the dump.

This area appears promising for further prospecting at depth along the vein zone, as it is on the French Gulch fracture zone midway between the Brown Bear and Gladstone mines. The workings of the Three Sisters mine probably are only a few hundred feet above the Copley Greenstone, and ore shoots of the type found at the Milkmaid and Washington mines might be expected just above the Copley contact.

Tom Green mine

The Tom Green mine is at an altitude of about 3,200 feet on the north side of the same ridge as the Summit mine, and on the same vein system as the Summit. According to Brown (1916, p. 800), three parallel veins strike about north and dip 45° E. One of these veins, probably the Brown vein (see description of Summit mine), was productive from 1890 to 1913. Brown (1916, p. 800) states that the vein has a slate hanging wall and a porphyry footwall. A longitudinal projection supplied by the present owners of the Summit mine shows that the Tom Green ore shoot was mined throughout a rake length of at least 550 feet and a width of 150 feet. Average thickness of the ore shoot was apparently about 2 feet. The ore is free milling and the gold evidently was mainly in quartz as in the Summit mine.

Averill (1939, p. 154) reports that during the late 1930's an adit, 280 feet lower than the older workings shown on plate 5, was driven 500 feet into the hill to reach a point vertically beneath the older stopes. This adit was not seen during the 1956-1957 field work, but as the dip of the main vein is 40° to 65° E., the adit described by Averill was probably driven 150 to 200 feet too far to the west to intersect the vein.

Venecia(?) mine

In the extreme northwest corner of the French Gulch quadrangle are several short adits thought to be part of the Venecia mine, which lies mostly to the west in the Weaverville quadrangle. These workings are in greenstone and in "birdseye" porphyry and shale just above the Copley Greenstone contact. Averill (1933, p. 56) states that three vertical veins, mostly in greenstone, were worked at the Venecia and that

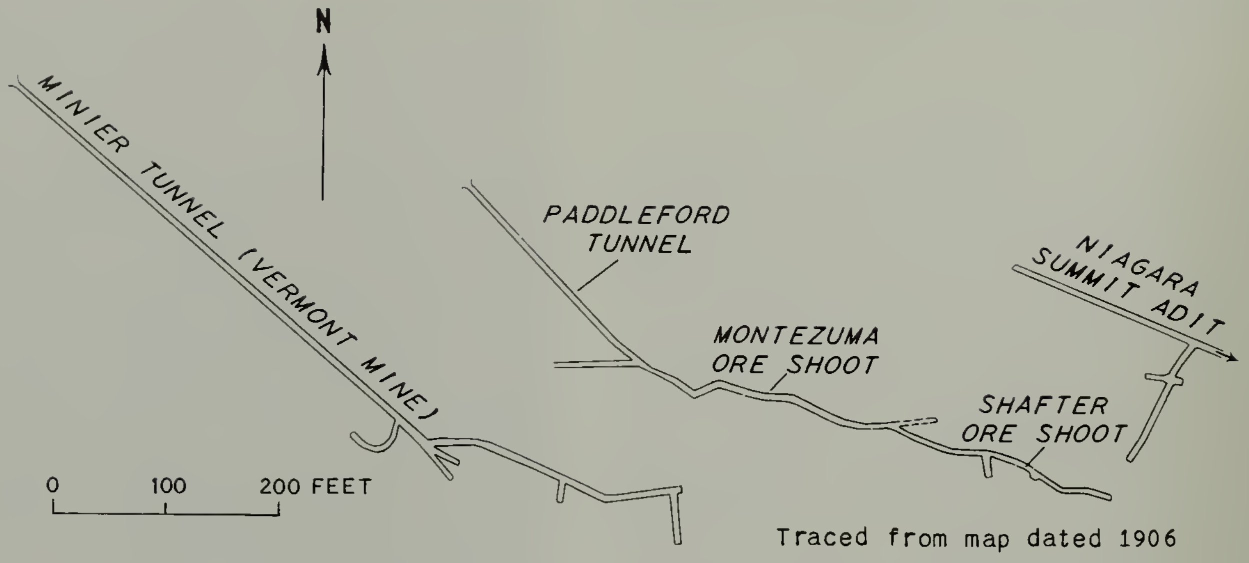


Figure 9. Map of the Vermont and Montezuma mines, Trinity County, California.

the ore was quartz containing iron, lead, and zinc sulfides. Production is not known.

Vermont and Montezuma mines

These mines, at an altitude of nearly 4,000 feet, are just west of the main divide forming the boundary between Shasta and Trinity Counties, and are inferred to be on the same northwest-striking fault zone as the Niagara Summit and Scorpion mines. The Vermont is reportedly owned by A. L. Brown, and the Montezuma by E. M. Clark, both of French Gulch. Information collected by O. H. Hershey in 1927 and kindly furnished to the writer by E. M. Clark indicates that the Montezuma may have produced more than 7,150 ounces of gold. Production from the Vermont is not known.

The mines are in a vein that strikes N. 60° W. and dips about 70° SW. The vein is in the lower unit of the Bragdon Formation and, where seen at the surface near the portals of adits, has a shale hanging wall and quartz porphyry footwall. Dikes of "birdseye" porphyry also crop out in the immediate area. Hershey's data indicate that the ore shoot mined at the Montezuma, which is higher on the hill than the Vermont, extended 350 feet southeastward towards the Niagara Summit adit. Hershey also found several subsidiary veins striking N. 80° E. and branching from the main vein on the west side of the ridge. The ore shoots apparently rake west at angles of about 50°.

In view of the continuity of the main vein for nearly a mile on strike, its favorable stratigraphic position in the lower unit of the Bragdon Formation, and the presence of branching veins, additional ore shoots may be found at depth in this area, particularly at intersections betwen the main vein and subsidiary veins.

Figure 9 is a map made in 1906 of the Vermont, Montezuma, and part of the Niagara Summit mines supplied to the writer by Mr. E. M. Clark.

Washington mine

The Washington mine is in the eastern end of a prominent ridge on the west side of French Gulch, across from the Milkmaid and Franklin mines. The mine was discovered in 1852 and is one of the oldest in the state (Ferguson, 1914, p. 64). It is developed by about six principal levels extending through a vertical distance of about 450 feet (pl. 6), and by numerous pits and trenches. Data on total production from the Washington mine are incomplete and contradictory; estimates range from 50,000 to 100,000 ounces of gold. Ferguson's (1914, p. 64) report of production of 28,500 ounces by 1890 seems fairly definite.

During 1956-1957 only the I level was accessible and was mapped. Mr. J. H. Scott, owner of the mine, kindly furnished additional maps, sections by K. C. Eisenhauer and A. H. Merrill, and reports. Mr. Henry Carter, caretaker, was most helpful in guiding us around the property and in recounting some of the history of the area.

The Washington mine is on the south flank of the arch that exposes the Copley Greenstone in French Gulch just to the north; the main mineralized zone is along the contact between the Copley Greenstone and the Bragdon Formation. Sills and dikes of quartz porphyry and "birdseye" porphyry are intruded along this contact in many places and also cut the underlying greenstone and overlying shale.

As at the Franklin mine, two veins have been worked at the Washington. One along the contact between greenstone and shale strikes generally north and dips irregularly eastward at an average angle of about 45°. Just below the I level, at an altitude of about 2,200 feet, the dip becomes more gentle and the contact between the greenstone and shale intersects the hillside and clearly projects eastward across French Gulch to the Franklin and Milkmaid mines area. The Bragdon Formation near the greenstone contact in the Washington mine is reported to be shiny black, highly sheared graphitic material that commonly contains thin layers of quartz arranged about parallel to the contact. This was the most highly mineralized zone but virtually none of it was seen during field studies in 1956-1957. It was worked along a strike length of about 500 feet in the upper levels and downdip for about 700 to 800 feet, nearly to the I level (pl. 6). From the information at hand it appears that a large percentage of this strongly mineralized eastward-dipping contact zone was worked, and that prospects for additional ore at this horizon would be mainly south of the present workings.

A second vein system strikes about N. 70° E. and dips on the average almost vertically. It is well exposed for about 1,000 feet on the I level and was drifted on for an even greater distance on the H level. It is almost entirely in the Copley Greenstone and, where seen on the I level, ranges from a few inches to about 3 feet thick. It was stoped in a few places where small pockets of ore occurred at the intersection of two or more veins.

The I level was reportedly driven mainly to recover ore exposed below H level, and about 2,400 ounces of gold was taken from the interval between H and I levels.

Sparse pyrite and calcite are present locally in the vein, and pyrite is disseminated in the adjacent greenstone. Ferguson (1914, p. 65) also reports the presence of galena, sphalerite, and arsenopyrite. As in the Milkmaid and Franklin mines, visible gold was found mostly in association with galena; thus galena may generally be regarded as a favorable indicator of gold.

The oxidized outcrop first mined in the Washington area was extremely rich and ran as high as 28.5 ounces of gold per ton (Ferguson, 1914, p. 66).

Muletown district

A small gold mining area in the vicinity of Mule Mountain, east of Clear Creek, is known as the Muletown district. The principal mines are the Potosi and Great Western, but production has been small. Most of the veins trend northeast and seem to show a spatial relationship to the Clear Creek plug and another small apophysis from the Shasta Bally batholith. A genetic relation to the batholith and its apophyses, as is also inferred for the French Gulch-Deadwood district, seems likely.

Great Western mine

This mine is in veins along two northeast-trending vertical fractures 15 feet apart, associated with a fine-grained mafic dike in the Mule Mountain stock. The location and strike of the deposit suggest that it may be along the same fracture system as the Potosi vein. According to Averill (1933, p. 29) the Great Western vein is a few inches to about 3 feet thick and was traced for about 1,000 feet along strike. It is composed of quartz and contains pyrite and free gold. The ore mined averaged about ¾ ounce of gold per ton but production was small. The deposit was worked from a few pits and two adits.

Potosi mine

This mine was discovered in the late 1800's and yielded some high-grade ore about 1890 (Averill, 1933, p. 44-45). The ore is in a quartz vein containing pyrite and free gold. The vein is mostly in the Copley Greenstone but lies just southeast of and roughly parallel to the border of the Clear Creek plug. One ore shoot 100 feet long by 4 to 16 inches thick has been stoped. The deposit was opened by pits, short adits, and three shafts, one 90 feet deep.

South Fork district

The South Fork mining district, north of Igo and almost entirely within the Shasta Bally batholith, is noted mainly as a producer of silver but has yielded some gold. According to Tucker (1922, p. 313), silver ore was first discovered in the district in 1856. The Silver Falls-Chicago Consolidated mine, discovered about 1866 and yielding around $1 million, was by far the largest producer. In the early years the ore was shipped by wagon, river boat, and sailing vessel to Swansea, Wales, for treatment, but later was treated locally in a 15-stamp mill. Nearly all the veins in this district strike northeast and dip southeast (pl. 2). Many of the ore shoots occur where veins intersect at acute angles. Quartz is the principal gangue, and ore minerals reported by Tucker (1922, p. 315) and others include tetrahedrite, galena, sphalerite, pyrite, native silver, gold, and chalcopyrite. Brief descriptions of individual mines are given below.

Big Dyke mine

This silver mine is about 4 miles northwest of Igo, well within the Shasta Bally batholith. According to Laizure (1921, p. 526), it was discovered during the 1800's. Production is unknown although a shipment of ore to a smelter at Kennett, probably around 1920, is said to have averaged 300 ounces per ton in silver (Tucker, 1922, p. 319). The Big Dyke vein and a series of veins roughly parallel to it strike N. 50° to 60° E. and dip steeply, mainly southeast. The vein is about 3 feet thick and the vein material is quartz and altered granitic rock. Argentiferous galena, tetrahedrite, pyrite, sphalerite, native silver, and minor gold are the ore minerals. Oxidation extends to depths of 20 to 50 feet. The vein was worked from a number of pits and adits, and from a shaft 153 feet deep.

Climax prospect

This prospect, about 3 miles north of Igo, on the South Fork of Clear Creek, differs from the other deposits of the South Fork district in that it is partly on the contact between the Shasta Bally batholith and the Copley Greenstone as well as within the batholith. The workings are along three veins. A main vein strikes N. 10° E. and dips 50° E. (Tucker, 1926, p.

205). Another vein, parallel to this, lies 100 feet west within the batholith, and a third vein 100 feet still farther west, strikes N. 20° to 40° E. and dips steeply southeast. The third vein should intersect the main vein north of workings that were in existence in 1926 (Tucker, 1926, p. 205).

The main vein is described by Tucker as "carbonized slate cut by numerous stringers of quartz". Sulfide minerals include pyrite, chalcopyrite, galena, and sphalerite. Tetrahedrite, native silver, and minor gold are the chief ore minerals. A small shipment of high-grade silver-lead-zinc ore was made in 1922 but the total production is not known.

Continental mine

This silver mine is on South Fork, 4 miles northwest of Igo, and about 2 miles inside the boundary of the Shasta Bally batholith. One of two veins on the property strikes N. 45° E. and dips 80° SE.; the other strikes N. 10° E. and dips steeply east. Tucker (1922, p. 320) reports that the vein striking N. 45° E. was drifted on for 200 feet at a depth of 200 feet below the outcrop and ranged from 8 inches to 3 feet thick. Vein material is quartz and altered granitic rock. Like the other deposits in the South Fork district it is mineralized with argentiferous galena, tetrahedrite, sphalerite, pyrite, native silver, and minor gold. Oxidation extends to a depth of 20 to 50 feet. The ore was milled in a 6-stamp mill during the 1880's (Tucker, 1922, p. 320), but the production is not known.

Great Falls (Ballau) (Manzanita) mine

This gold mine, in the South Fork district about 6 miles northwest of Igo, is in a series of quartz veins that strike generally N. 20° E. and dip nearly vertical. The wall rock is the Shasta Bally batholith. The main vein ranges from 8 inches to about 2 feet thick and consists of quartz containing pyrite and free gold. The mine is unique in a district that otherwise is known mainly for silver; it is owned by R. S. Ballou of Igo and is opened by at least seven adits and one shaft. Production has been small.

Silver Falls-Chicago Consolidated mine

This mine, about 4 miles by road northwest of Igo, was the largest producer in the South Fork mining district. It was discovered in 1866, and total production, mainly before 1900, was reportedly about $1 million (Tucker, 1926, p. 202). The ore was mostly silver but concentrations of high grade gold ore were found locally. The silver-bearing mineral (Tucker, 1926, p. 204) is tetrahedrite, associated with galena, small amounts of pyrite, sphalerite, chalcopyrite, and gold. The veins, which are in quartz diorite of the Shasta Bally batholith, strike N. 45° E. to N. 60° E., and dip steeply north to steeply south. They range from 10 inches to 2 feet in thickness, and rake northeast.

The Silver Falls-Chicago Consolidated mine is developed by several thousand feet of workings, including a shaft 210 feet deep and a crosscut 3,000 feet long. This crosscut is at an altitude of 1,400 feet, or about 600 feet below the outcrop of the principal veins. Although fractures were intersected, little vein material was encountered, suggesting that the veins may have pinched out at this depth.

Tucker (1926, p. 204) reports enrichment at the intersections of veins that converge upward. Apparently this enrichment is within the zone of oxidation which is reported to extend to depths of 10 to 50 feet. Tucker (1922, p. 318) published a map and detailed description of the Silver Falls-Chicago Consolidated mine.

White Star mine

This small silver mine, also known as the Crystal mine, is 3 miles northwest of Igo, on Andrews Creek. The mine is on three subparallel veins 20 to 40 feet apart that strike northeast and dip 80° SE. (Tucker, 1922, p. 319). The veins, which are in the Shasta Bally batholith, contain native silver, tetrahedrite, sphalerite, pyrite, chalcopyrite, and some gold.

The principal work was on the middle of the three veins. A crosscut tunnel 320 feet long intersects all three veins at a depth of about 90 feet, and the two most southerly veins were stoped above this level. Where these two veins intersect a few feet northeast of the crosscut, an ore shoot 2 to 5 feet thick, 60 feet long, and presumably raking northeast, was formed. Shipments of good grade silver ore were made to a smelter, but the total production was only a few thousand dollars.

Whiskeytown district

This district lies in the east central part of the French Gulch quadrangle. It includes the Mad Mule, Truscott, and Mount Shasta gold mines, and the Ganim gold-talc mine as well as numerous lesser mines and prospects. Production from this district is estimated at 68,700 to 71,500 ounces of gold. The geology of the various deposits differs markedly. The Mad Mule and Truscott mines are mainly along contacts between shale of the Bragdon Formation and tabular bodies of "birdseye" porphyry, and are thus similar in character to some deposits of the French Gulch-Deadwood district. On the other hand, the Mount Shasta and Ganim mines are along northwest-trending structures in the Balaklala Rhyolite and Copley Greenstone respectively, whereas the Mascot, Eiller, and numerous other small deposits are in veins that strike generally east in the Mule Mountain stock.

Veins in the Copley and Balaklala Formations and in the Mule Mountain stock were much less productive than those in or adjacent to the Bragdon Formation, and for this reason the Whiskeytown district has a low future potential for gold as compared to the French Gulch-Deadwood district. The larger mines in this district are briefly described below.

Eldorado mine

This mine is on the west side of Mill Creek just south of Tower House. According to Ferguson (1914, p. 56), the property was located about 1885 by William Paul. Production to 1912 was estimated to be 1,200 ounces of gold. The mine was also operated from 1912 to 1919 (Logan, 1926, p. 171), but its production during that period is not known.

The workings were inaccessible during 1956-1957 and about all that could be learned from surface exposures was that the vein is along a steeply dipping fault contact between the Copley Greenstone and shale of the Bragdon Formation. The following description of the geology is taken from Ferguson (1914, p. 56):

"The lode lies along the fault contact of meta-andesite and slate, which strikes about N. 20° W. and dips 50° to 70° E. * * * . There is much gouge along the contact and a part of the faulting has been oblique to the original contact, resulting in sharp wedges of slate that enter the meta-andesite at small angles and small lenses of much-crushed slate that are included in the meta-andesite at 2 feet or less from the contact.

"Quartz occurs in small lenses about 2 feet in width along the slate walls and in meta-andesite, especially near the slate. The quartz is somewhat drusy, though the vugs are all small, never more than 2 centimeters in greatest diameter. The vein quartz is much mixed with fragments of meta-andesite, whose uncertain boundaries imply some replacement. A little sericite accompanies the altered meta-andesite in places. No calcite was seen in any of the ore.

"The gold occurs entirely in pockets in the quartz and gouge. The richest pocket found, from which $2,500 worth of gold (about 122 ounces) was taken, was entirely in the gouge between quartz and meta-andesite. Other rich pockets are in the form of quartz veinlets, generally less than an inch wide, in the meta-andesite near the infaulted lenses of slate. These veinlets carry visible gold in association with specks of iron oxide and in small flakes lining minute druses. So far as could be observed, the rich quartz was free from manganese."

Ferguson (1914, p. 40) regards the Eldorado deposit as an intermediate type between the fissure veins in the Bragdon, and typical pocket deposits. The quartz along the faulted contact between the Copley and Bragdon is manganiferous. Mining was profitable only in the upper levels of the Eldorado, near the surface, and the fineness of the gold was notably lower than the average for the district. The grade was about ¾ ounce per ton on the average.

Gambrinus mine

This mine, which is on the east side of Whiskey Creek opposite Whiskeytown, was discovered about 1870 (Ferguson, 1914, p. 50). Its total production to July 1912 was about 6,170 ounces of gold. Production since then is not known. Four quartz veins ranging in strike from west to N. 50° W. and in dip from 45° N. to vertical were worked, mostly above the creek level. The three northernmost veins form irregular lenses 3 to 4 feet thick in a crushed zone in the Balaklala Rhyolite near a body of Copley Greenstone. Metallic minerals in the veins are pyrite, free gold, and locally chalcopyrite (Ferguson, 1914, p. 51). The quartz in the northwesternmost vein is manganiferous. No calcite was seen in the ore. The tons of ore mined and average grade are not known.

Ganim gold-talc mine

This mine, about 2 miles north of Whiskeytown is on a northwestward-trending shear zone in Copley Greenstone. A body of talc about 60 feet wide lies between two masses of siliceous material containing pyrite and minor chalcopyrite, sphalerite, and galena (Averill, 1933, p. 26-27). The siliceous material also contains some gold. In the general vicinity are quartz veins that were worked in a small way, one of which assayed about ½ ounce gold per ton. The property is owned by J. L. Ganim.

During World War II the talc deposit was mapped by B. M. Page and L. A. Wright of the U.S. Geological Survey. A few copies of these maps were printed in 1943 as U.S. Geological Survey Strategic Minerals Investigation Preliminary Maps.

Mad Mule mine

One of the most famous gold mines in the French Gulch quadrangle is the Mad Mule mine about 5 miles north of Whiskeytown. The gold is found along the hanging wall and footwall of a sill-like body of "birds-eye" porphyry about 100 to 150 feet thick that marks the contact between the Bragdon Formation above, and the Balaklala Rhyolite and Copley Greenstone below. The sill strikes about east and dips 40° to 50° N. in the western part, but steepens to near vertical farther east. The gold does not occur in a quartz vein, but as leaves and platy masses in calcite at irregular bends, called "points", along the contact. The "points" are formed by intersecting fractures or by small sharp folds. The richest ore was in "points" along the hanging wall of the porphyry sill close to shale. Gold also occurred along the footwall of the sill. Ferguson (1914, p. 54) reports that the largest single piece of gold taken from the Mad Mule mine was in the form of a plate about a quarter of an inch thick and weighing more than 100 ounces. The mineralized zone is about a mile long and has been exploited by numerous adits, raises, and surface diggings. Averill (1933, p. 36) reports that according to an estimate by a local miner, about 8 miles of underground workings were driven. The total production was about 50,000 ounces of gold, according to estimates quoted by Ferguson (1914, p. 52) and Averill (1933, p. 36).

In addition to calcite lenses in which most of the gold occurs, Ferguson (1914, p. 53) describes small quartz stringers 1 to 2 inches thick along the contact between shale and porphyry and in shale and porphyry for distances of a few feet from the contact. The quartz is honeycombed with cavities probably formed by the leaching out of calcite. Many of the cavities are partly filled with manganese oxide. Veinlets of pyrite, reported to be auriferous, also cut the shale, and disseminated pyrite cubes occur in the porphyry. No other sulfides were reported.

Ferguson (1914, p. 52-54) regards the Mad Mule mine as an excellent example of a pocket-type deposit in which the gold content is related to the present erosion surface. In support of this view he mentions that: (a) all the gold mined to 1914 had come from the calcite "points", (b) all the "points" found were comparatively near the surface, the deepest being not over 250 feet vertically below the surface, (c) the intersection of quartz stringers containing manganese oxide with calcite of the "points" was generally regarded as a favorable indicator of a rich ore pocket, (d) the "points" mined were chiefly on the hanging wall of the dike, and (e) the pockets were all closely connected with existing watercourses. A significant amount of secondary enrichment of gold doubtless took place at the Mad Mule mine.

Nevertheless, a hypogene gold deposit of considerable extent must also have been present originally, either along the same porphyry contacts as the known deposits, or in veins in overlying shale that were removed long since by erosion, the gold remaining as a concentrate at lower horizons. The hypogene vein system probably trended about east, and was located approximately above the present Mad Mule Gulch. In view of the large amount of work done in the Mad Mule area, and of the absence of gold along the hanging wall of the porphyry dike at depths greater than about 250 feet, it is unlikely that important new ore bodies will be found.

Mad Ox mine

This mine is on Mad Ox Gulch about 5 miles north of Whiskeytown. It is on a vein in sheared greenstone of the Copley and, according to Ferguson (1914, p. 51), strikes N. 22° to 33° E. and dips vertical to very steeply southeast. The vein ranges in thickness from a thin layer of gouge to about 4 feet, and the maximum stoped length is about 100 feet. The ore is iron-stained quartz with minor calcite. Averill (1933, p. 35) mentions two ore shoots 100 feet apart, each 60 feet long and 2 to 4 feet thick; and a third shoot about 50 feet long in which the ore averaged about a third of an ounce of gold per ton.

Mount Shasta mine

This mine, which is near the southern end of the large pendant of the Balaklala Rhyolite in the Mule Mountain stock, was discovered in 1897 (Ferguson, 1914, p. 47). Total production, mostly prior to 1905, is estimated at about 8,500 ounces of gold. Ore was in two parallel veins about 50 feet apart that strike N. 20° to 30° W. and dip steeply southwest at the surface. However, Ferguson (1914, p. 48) reports that at depth the dip changes to northeast. The veins were worked on seven levels to a depth of 465 feet. A shaft was sunk to a depth of 193 feet below the seventh level but in 1913 it was abandoned (Averill, 1933, p. 38). The rake and strike length of the veins are not known, but the maximum thickness is about 5 feet.

The ore was white quartz containing small crystalline masses of calcite. In places the quartz was strongly shattered. Pyrite was the only metallic mineral that occurred in any abundance, but tiny scattered specks of molybdenite were seen by Ferguson (1914, p. 48) on the seventh level. The mine produced 4,072 tons of ore averaging a little over 2 ounces of gold per ton from the first six levels. Eighty-eight tons of oxidized surface ore was slightly richer.

Truscott mine

This mine is west of the Mad Mule mine in the ridge east of Grizzly Gulch. It was discovered in the 1880's (Ferguson, 1914, p. 54), and by 1912 had produced about 2,850 ounces of gold. It was worked from several adits at levels 40 feet apart. The mineralized zone is along the footwall contact of a sill-like body of "birdseye" porphyry about 300 feet thick that intrudes the Bragdon Formation. The contact strikes about N. 20° E. and dips 60° NW. The gold is in thick lenses of quartz separated by a few tens to a few hundred feet of unmineralized wall rock. The only lens developed was about 100 feet long and carried about ½ to ¾ ounce per ton in free gold (Ferguson, 1914, p. 55). The gangue is white quartz with minor calcite and much shale as inclusions and streaks. Small veins of manganiferous quartz branch out into the porphyry from the main vein. Some of these reportedly were very rich in gold. Pyrite was the only sulfide mineral. Additional lenses of quartz probably occur at depth along the footwall and possibly along the hanging wall of the porphyry sill. However, the quartz lenses are probably irregularly distributed and hence may be difficult to find.

Placer deposits

Much placer mining and some dredging have been done along Clear Creek and many of its tributaries since the 1850's. As might be expected from the distribution of lode deposits, the richest placer areas have been Whiskey Creek and French Gulch. In some localities the gravels were worked at least three times—first by the contemporaries of the '49ers, later by the Chinese miners, and finally by dredging. Production records are scarce, but probably several tens of thousands ounces of gold was produced from placers.

In addition to the recent deposits in stream channels, older high-level gravels were worked near Igo and in a few places along Clear Creek between Whiskeytown and the village of French Gulch. Pocket deposits along the contact between the Copley and Bragdon Formations were placered. The placer deposits were not studied in detail for the present report. Diller (1914), Averill (1933, 1939), and Logan (1926) described some of the placer operations in detail.

Greenhorn mine

The Greenhorn mine is on U.S. Highway 299 about 5 miles east of the western boundary of the quadrangle. It lies about 9 miles west of the main group of massive sulfide deposits that make up the West Shasta copper-zinc district and is the only known sulfide deposit in the quadrangle not described by Kinkel and others (1956). The deposit is developed by workings at ten different levels ranging from an altitude of 1,833 feet to 2,269 feet (pl. 7).

The deposit was located in the early 1900's, and in 1919 the claims were purchased by the Greenhorn Mining Company. During the period 1919-1934, this company did about 12,000 feet of exploration and development work and shipped about 50 carloads of high-grade copper ore. During 1938-1939 an additional 2,000 feet of development work was done. The property was later leased to Willow Creek Mines, Inc., which mined and milled about 75,000 tons of gossan that yielded $218,000 in gold and silver. From the beginning of World War II until 1956 no work was done on the property, but during 1956-1957 Miami Copper Company did additional exploration work under a lease-option arrangement with W. K. Gonyea, the present owner.

Geology. The principal formations in the Greenhorn mine area are the Balaklala Rhyolite and the Bragdon Formation. These are within the outer part of the aureole of the Shasta Bally batholith and are slightly to moderately metamorphosed. The Balaklala is largely recrystallized and in most places exhibits a weak to prominent foliation that probably parallels bedding. The shaly rocks of the Bragdon Formation are now mostly phyllite. A few dikes and sills of quartz porphyry not affected by contact metamorphism intrude the Balaklala and Bragdon Formations.

The main contact between the Balaklala and Bragdon Formations strikes about N. 60° W., and dips 30° to 50° NE. Foliation is about parallel to the contact. The Balaklala is probably separated from the overlying Bragdon by the Spring Creek thrust, although this relation was not clearly determined at the Greenhorn mine. Several steep normal faults that strike nearly north, and dip mostly east, further disrupt the rocks of the area. The largest of these forms the eastern limit of workings on the two lower levels (pl. 7), and probably has a dip-slip displacement of about 50 feet with the east side downdropped.

The sulfide bodies are tabular replacement deposits in the metamorphosed Balaklala Rhyolite. They are marked at the surface by a prominent fairly continuous gossan, now partly removed by mining. They strike northwest and dip northeast, about parallel to foliation or shearing in the rhyolite and mainly occupy a zone about 100 feet below the Bragdon contact. According to maps and other data supplied by Clayton T. McNeil, mining engineer from San Francisco, who represents the present owner, the tabular bodies are about 25 to 30 feet thick. Their lateral and downdip extent could not be determined with certainty during the present study, owing to the inaccessibility of most workings. The distribution of workings and information on older maps suggest that the sulfide masses and their gossan equivalents are more or less continuous from the surface down to the No. 2 level (pl. 7, longitudinal section). This is also suggested by the fairly continuous gossan shown on older maps. On the other hand, engineers who examined the deposits when the workings were open describe the sulfide masses variously as "tabular lenses" and as "bed-like masses of greater horizontal than vertical extent". Most sulfide deposits in the West Shasta copper-zinc district are lenticular (Kinkel and others, 1956), and a group of sulfide lenses along one or possibly two favorable heavily mineralized zones in the rhyolite is a much more likely shape for the Greenhorn deposits than a continuous tabular mass through the entire extent of the existing workings.

Contacts between the massive sulfide and the host rock are sharp in some places but gradational through a zone of heavily to moderately pyritized rock in others. In the incompletely pyritized rock the sulfide is commonly all pyrite arranged mostly in layers along foliation planes, and the mineralization thus accentuates foliation. Locally, even in the massive sulfide, distinct traces of this foliation inherited from the host rock are retained. This and the gradational nature of the contacts of the massive sulfide in many places indicates a replacement origin.

Sharp contacts between sulfide bodies and wall rock are commonly marked by a layer of clayey gouge ranging from a fraction of an inch to several inches thick. The planar shape of most of these gouge layers indicates that they are along fractures and faults. In places the gouge contains uncrushed crystals of pyrite. The presence of these crystals and the scarcity of slickensided surfaces on the sulfide bodies suggests that most faults are of pre-mineral age, and that some may have served as feeder channels for mineralizing solutions. A few of the faults probably had post-mineral movement. Chief among these is the through-going fault that forms the eastern limit of the No. 1 and No. 2 levels. This fault was not seen during the present work, but maps made during earlier years by company geologists indicate an offset of the gossan along this fault in the upper levels of the mine. The fault may have a post-mineral dip-slip displacement of about 50 feet, the east side being downdropped (pl. 7, section A-A′). Distribution of gossan outcrops at the surface also suggest this post-mineral movement. In the West Shasta copper-zinc district, where both pre-mineral and post-mineral faults are present (Kinkel and others, 1956, p. 83-84), many of the pre-mineral faults have some post-mineral movement. The same condition probably exists in the Greenhorn mine where the geologic environment is generally similar to that of deposits in the West Shasta district.

If the fault referred to above in the eastern part of the mine has a post-mineral dip-slip movement of about 50 feet, additional massive sulfide may exist on the eastern downdropped side between coordinates N. 2500 and N. 3000. This area has been only silghtly explored although it was penetrated by a long crosscut from the No. 3 level and by the No. 6 level. The No. 3 level may be above a downdropped sulfide block as suggested on sections B-B′ and C-C′, whereas the No. 6 level would be far below such a block. A vertical hole drilled from the surface to a depth of 213 feet by Miami Copper Co. in the vicinity of coordinates N. 2790, E. 3830 failed to penetrate sulfide, but may not have extended far enough.

The massive sulfide is similar to that of the West Shasta district described by Kinkel and others (1956). Where fresh, it is brassy in appearance, and consists of about 90 percent pyrite; subordinate chalcopyrite is interstitial to the pyrite grains. Assays indicate that the average copper content of the massive sulfide is a little more than 2 percent. Quartz in minor amounts also is interstitial to pyrite in the massive sulfide. Most of the massive sulfide exposed on the No. 1 and No. 2 levels in 1957 was friable material that readily broke down to sand when probed with a pick. In a few of the places where this friable sulfide is banded, thin dark layers of sooty chalcocite parallel the banding.

The oxidized outcrop is typically reddish-brown, hard, siliceous, locally porous and cavernous limonite gossan. Thin septa of silica give some of it the appearance of a cellular porous sponge. No oxidized copper minerals were seen in the gossan, indicating that the copper was probably removed by acid generated by the oxidizing pyrite. Part of this copper may be present, chiefly as chalcocite, in a zone of supergene enrichment in the upper part of the massive sulfide and between the limonitic gossan and the sulfide, but much of it was probably removed in surface runoff. Most of the gossan derived from massive sulfide reportedly was residually enriched in gold throughout, and it was enriched in silver in its lower part near the boundary with the sulfide. Data indicate that the overall pattern of enrichment at the Greenhorn mine is quite similar to that at Iron Mountain as described by Kinkel and others (1956, p. 99). In the West Shasta district only gossan derived from massive sulfide is enriched in precious metals. Iron-stained limonitic material derived from heavily pyritized rock rarely contains precious metals. Similar conditions probably obtain in the Greenhorn area but detailed information is unavailable.

Geophysical Survey of the Iron Mountain Mine

By C. H. Sandberg

Geophysical investigations were made in the Iron Mountain area, Shasta County, California, during 1951 and 1952 to determine the effectiveness of various geophysical methods in outlining massive-sulfide deposits. Electrical-resistivity, natural-potential, and magnetometer measurements were tested over the Brick Flat ore body of the Iron Mountain mine. This deposit is considered to be representative of the massive-sulfide deposits in the district. The ore body had been delineated by drilling but not touched by mining operations.

I wish to thank the management of the Mountain Copper Co., Ltd., and especially C. W. McClung, for making mine information available and granting accessibility to the property.

I am also indebted to S. N. Sengupta and M. N. S. Rao, International Cooperation Administration participants from India, for assistance in making measurements and discussions of results.

A. R. Kinkel, Jr., W. E. Hall, and J. P. Albers, who studied for the geology of the area, also rendered physical assistance in making measurements and aided in the interpretation of results.

Geology

The geology of the mine area has been described in detail (Kinkel and Albers, 1951, Kinkel and others, 1956) and only those features which particularly relate to the geophysical measurements are reviewed here.

The two major rock units encountered in the geophysical survey were the Copley Greenstone and the Balaklala Rhyolite. The Copley Greenstone, of probable Devonian age, consists primarily of metamorphosed mafic flows and pyroclastics. No ore deposits are known to occur in the greenstone in this area. It is pyritized only in small, local areas. The Balaklala Rhyolite conformably overlies the Copley Greenstone. The Balaklala Rhyolite consists of a series of silicic flows and pyroclastic rocks, together with dikes and plugs that were feeders for the extrusive material.

The ore bodies occur as massive-sulfide replacements in the Balaklala Rhyolite. The Brick Flat ore body is a representative massive-sulfide deposit composed almost entirely of pyrite. The ore is about 95 percent acid soluble. The top of the ore body is between 100 and 200 feet below the surface. Most other deposits in the district have been found at greater depths.

The geology of the district has been mapped on a scale of 1:24,000 and the mine area on a scale of 1 inch = 200 feet. These maps were used in the geophysical survey.

Geophysical Methods

Resistivity

From theoretical considerations, it should be possible to outline a conductive body such as massive pyrite overlain by less conductive rocks by use of any of the accepted electrical methods. No electromagnetic equipment was available, hence that method was not tried. Resistivity-depth profiles were run at three stations using the Lee-partition method and a commutated current. The locations of these stations are shown on plate 8. Station R_1 overlies sulfide at a depth of about 100 feet. Stations R_2 and R_3 are in barren areas.

The resistivity-depth profiles (fig. 10) are similar; the resistivity decreases with increased electrode separation. The overall apparent resistivity of Station R_1 is less than that of the other two stations but there is nothing uniquely different in the general character of

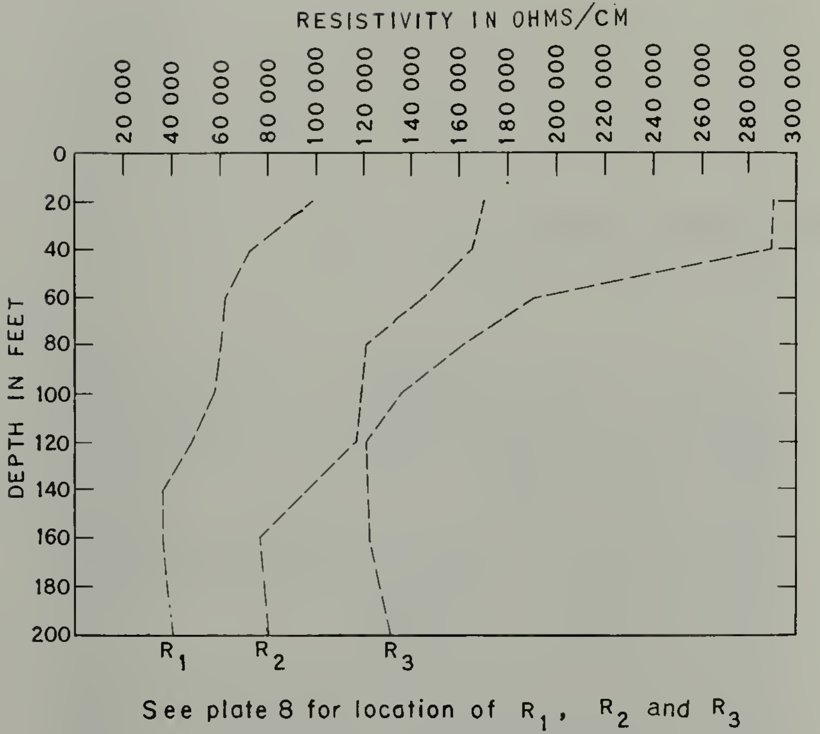


Figure 10. Resistivity-depth profiles, Iron Mountain mine, Shasta County, California.

the curves; thus they do not offer a reliable basis on which to predict ore.

If we accept these three sets of curves as reliable and representative of what can be expected using resistivity equipment under conditions prevailing in this area, it is evident that resistivity methods will not be suitable for locating massive-sulfide deposits under conditions prevailing in the West Shasta copper-zinc district. Horizontal profiling was not used because, by the character of the resistivity-depth profiles, horizontal profiles can be predicted to be unreliable.

Natural potential

The ore body is below the natural water table, therefore oxygen-bearing surface water probably percolates downward into the ore. This oxygen-bearing water should produce a certain amount of oxidation of the pyrite which, in turn, should give rise to an electrochemical potential generated in the ore body. Preliminary potential test measurements in the area were encouraging and, as a result, a natural-potential survey was undertaken. Measurements were made along roads, trails, and natural openings insofar as possible.

The electrodes used in this survey were the copper-to-saturated-copper-sulfate solution type, commonly called nonpolarizing electrodes. Good electrical contact with moist soil was made using these electrodes. A shallow pot hole, 2 to 4 inches deep, was dug at each station to expose moist soil, therefore it was not necessary to wet the pot holes when making the measurements.

Reliable natural-potential measurements could not be made while the mine was operating, because a direct current electrical trolley haulage was used. As a consequence, all measurements were made on "off" hours, week-ends, and holidays.

The double reference point method was used to make all natural-potential measurements. This method affords a running check on measurements and serves to eliminate personal reading errors as well as to detect any stray currents. A brief analysis of the method is presented to facilitate a better understanding of the data and the discussion of results.

The usual method of making a natural-potential survey is to choose a fixed point as a "reference point". An electrode contact is established at this point and then by means of a moving electrode, contacts are made at various other points in the area under investigation. The potential difference between the fixed or reference electrode and the moving electrode is measured by means of a potentiometer or other suitable device. From these data it is theoretically possible to calculate the potential difference between the various points occupied by the moving electrode, provided equilibrium is established.

In practice, it is often found that the potential difference between two stations calculated from data obtained at the stations relative to different reference points or data using the same reference points but for repeat readings at another time do not agree. It is therefore evident that, under some conditions, either the potential of the reference point or the potential of at least one of the stations in question did not remain constant. The earth's potential field does not always vary uniformly even in limited areas and during relatively short periods of time.

The double reference point method was adopted in an effort to partially correct for this instability, afford some estimate of its probable magnitude, and at least indicate the lack of equilibrium.

This method, as the name implies, utilizes two fixed electrodes and one moving electrode. The reference points should be selected with the following factors in mind.

1. The points should be sufficiently far apart so that they will not both be subject to the same purely local conditions.

2. These reference points should be in accessible places where they can be easily identified and readily relocated.

3. The points should be selected so that either one or the other may be utilized as one of a second pair of reference points in the event the survey is extended beyond the originally planned limits.

4. Insofar as possible, the reference points should be located in areas representative of different environments within the geological setting. In general, it has been found advisable to avoid fault zones and well-drained unconsolidated gravel or sandy members as reference point locations.

Table 1. Geophysical data form.

Project Shasta Copper Sheet

Location Iron Mountain Redding, California Date 6/13/52

Traverse P_1 = R.P. 0 P_2 = R.P. No. 14

	1	2	3	4	5	6	7	8
Station	P_0P_1	P_0P_2	P_2P_1	Closure error	mid. pt. $\frac{1}{2}(P_0P_1 + P_0P_2)$	Adj. on sta. 674 on Col. No. 5	Adj. on sta. 674 on Col. No. 1	Adj. to sta. 674 on Col. No. 2
674	$-70.^{0}$	$+180.^{2}$	$-250.^{6}$	$-0.^{4}$	$+55.^{1}$	$0.^{0}$	$0.^{0}$	$0.^{0}$
675	$-108.^{0}$	$+143.^{0}$	$-250.^{8}$	$+2.^{2}$	$+17.^{5}$	$-37.^{6}$	$-38.^{0}$	$-37.^{2}$
676	$-63.^{0}$	$+188.^{5}$	$-251.^{0}$	$+0.^{5}$	$+7.^{7}$	$+7.^{0}$	$+7.^{0}$	$+8.^{3}$
677	$-53.^{4}$	$+199.^{5}$	$-251.^{0}$	$+1.^{9}$	$+73.^{1}$	$+18.^{6}$	$+16.^{6}$	$+19.^{3}$
678	$-69.^{5}$	$+180.^{7}$	$-250.^{5}$	$-0.^{3}$	$+55.^{6}$	$+0.^{5}$	$+0.^{5}$	$+0.^{5}$
679	$-115.^{0}$	$+135.^{5}$	$-250.^{0}$	$+0.^{5}$	$+10.^{2}$	$-44.^{9}$	$-45.^{0}$	$-44.^{7}$
680	$-73.^{6}$	$+175.^{0}$	$-249.^{6}$	$-1.^{0}$	$+50.^{7}$	$-4.^{4}$	$-3.^{6}$	$-5.^{2}$
681	$-32.^{5}$	$+216.^{2}$	$-249.^{4}$	$-0.^{7}$	$+91.^{9}$	$+36.^{8}$	$-37.^{5}$	$+36.^{0}$
682	$-31.^{0}$	$+217.^{9}$	$-250.^{0}$	$-1.^{1}$	$+93.^{5}$	$+38.^{4}$	$-39.^{0}$	$+37.^{7}$

Notes: Col. No. 4 = $P_0P_2 - P_0P_1 + P_2P_1$.
(The notation used to indicate respective potentials has been dictated by the arrangement and numbering of the switches on the potentiometer used in making the measurements)
Col. No. 6 is obtained by subtracting $+55.^{1}$ (the value at Sta. 674) from each value in Col. No. 5.
Col. No. 7 is obtained by subtracting $-70.^{0}$ from each value in Col. No. 1.
Col. No. 8 is obtained by subtracting $+180.^{2}$ from each value in Col. No. 2.

The field procedure consists of measuring the potential differences between the fixed electrodes and the moving electrode and can best be illustrated by use of an example of field data obtained. This is shown on the data form (table 1). Columns numbered 1, 2, and 3 are the readings taken at stations 674 to 682; column 4 is the error of closure obtained by summing the three sets of readings in accordance with the Kirchhoff principle and should be zero under ideal conditions. The error of closure includes errors due to inaccuracies of instrument, errors in observation and recording, and errors due to potential drift of any of the points under measurement. This error is a qualitative measure of the reliability of the readings. It will be noted that each point is represented in two of the three sets of readings taken at each station. Hence, if a set of readings does not yield a satisfactory error of closure, a set of repeat readings will indicate the source of the error provided the error was due to drifting potential at only one point. It will also be noted that column 3 gives a running check on the behavior of the reference points P_1 and P_2. The values obtained in column 6 are an average in which all errors are included. Column 7 is independent of any errors due to P_2, and column 8 is independent of errors due to P_1. These various values serve as checks on the accuracy of the survey. Judicious consideration of all factors must be used in selecting the best probable value for repeat stations.

Table 2. Range of potential differences of reference points.

Reference Points		Range Potential Difference			Date
0	2	$-53.^{8}$ mv.	to	$-44.^{2}$ mv.	5/30/51
"	"	$-49.^{5}$	"	$-44.^{2}$	6/ 9/51
"	"	$-74.^{9}$	"	$-57.^{8}$	6/23/51
0	5	$+160.^{2}$	"	$+171.^{7}$	6/10/51
0	6	$+190.^{2}$	"	$+206.^{9}$	6/16/51
0	14	$-245.^{4}$	"	$-251.^{9}$	6/ 6/52
"	"	$-269.^{0}$	"	$-300.^{4}$	6/ 7/52
"	"	$-249.^{3}$	"	$-255.^{5}$	6/13/52
"	"	$-263.^{0}$	"	$-269.^{0}$	6/14/52
0	17	$-203.^{5}$	"	$-207.^{0}$	6/14/52
0	18	$-266.^{0}$	"	$-283.^{0}$	6/15/52
0	18	$-221.^{5}$	"	$-225.^{0}$	6/17/52
2	1	$-39.^{0}$	"	$-45.^{3}$	6/ 3/51
3	4	$-20.^{2}$	"	/$+36.^{7}$	6/ 2/51
5	7	$-118.^{8}$	"	$-174.^{5}$	6/17/51
6	8	$-237.^{4}$	"	$-268.^{5}$	6/18/51
7	9	-0.9	"	$-31.^{0}$	6/24/51
9	10	$-9.^{8}$	"	$-41.^{2}$	6/30/51
10	11	$+17.^{2}$	"	$+29.^{7}$	7/ 1/51
11	10	$-18.^{4}$	"	$-12.^{2}$	6/22/52
11	19	$-126.^{5}$	"	$-110.^{9}$	6/21/52
12	13	$+61.^{3}$	"	$+80.^{2}$	7/ 1/51
15	16	$+56.^{4}$	"	$+99.^{5}$	6/ 8/52

Table 3. Potential—time study of station 630.

Station 630—Dated June 7, 1952

Time	P.P_1	P.P_2	P.P_1	Calc[1] P.P_1	Calc[2] P.P_2	Med. value	Time min.	Probable[3] data error
12:07	+97.3	+20.0	+81.5	+99.4	+17.9	+58.6	0	+4.2
12:10	+89.2	+6.5	+81.1	+88.4	+7.3	+47.9	3	−1.6
12:22	+67.5	−20.0	+84.0	+65.7	−18.3	+23.7	15	−3.5
12:25	+62.1	−23.8	+84.2	+61.2	−23.0	+19.1	18	−1.7
12:27	+59.5	−27.8	+85.7	+58.7	−27.0	+15.9	20	−1.6
12:40	+54.8	−34.9	+87.4	+53.6	−33.8	+9.9	33	−2.3
12:48	+50.8	−35.0	+87.3	+51.5	−35.8	+7.9	41	+1.5
12:55	+50.0	−37.5	+88.3	+50.4	−37.9	+6.2	48	+0.8
1:04	+48.9	−44.6	+91.1	+47.7	−43.4	+2.2	57	−2.4
1:05	+47.2	−45.2	+91.7	+46.9	−44.9	+1.0	58	−0.7
Average value	+62.7	−24.2	+86.2	+62.4	−23.9	+19.2	..	−7.3*

[1] Calculated on formula P.P_1 = ½ (P.P_1 + P.P_2 + P_2P_1).

[2] Calculated on formula P.P_2 = ½ (P.P_1 + P.P_2 − P_1P_2).

[3] Calculated by Kirchhoff's Law P.P_2 + P_2P_1 + P_1P. (i.e. − P.P_1) = 0. ± error.

*Sum of errors (not random errors).

The double reference point method was amply justified on the survey at Iron Mountain. At times the reference points were found to change during the day; also, on different days the same set of reference points showed a marked difference in potential. The variation in potential between reference points is given in table 2.

Potential variations of as much as 65 millivolts were observed. Therefore, considerable trouble was encountered when trying to tie one day's work with another or one season's work with another. Generally the rate of change of potential was neither uniform nor unidirectional. Consequently the error introduced by variation of reference point potentials cannot justifiably be distributed uniformly over all the stations. The potential instability was not limited to the reference points. Table 3 gives the data on a short period "time-study" at station 630. In this case P_2 P_1 represents the reference points. During the period of test (58 minutes) the potential between P_2 P_1 changed by 10.2 millivolts and the potential between P_0 and P_2 changed by 65.2 millivolts. A graph of these data (fig. 11) resembles a decay curve and suggests diffusion of liquid or chemical reaction at the electrode contact as the possible cause of changing potentials. At other stations similar studies gave curves of different characteristics which indicate that the causes of these changing potentials are not simple.

The process of constructing an isopotential map becomes a process of essentially trial and error based on an overall analysis and evaluation of the data. Both mathematical and graphical methods were used in evaluating and adjusting the data. No attempt was made to correct for regional or terrain gradients. Potential measurements were made at 840 stations and the results contoured as an isopotential map (pl. 8) on a 50 millivolt contour interval. The map as presented is thought to be a fair representation of the composite potential picture of the area.

An analysis of the isopotential map is interesting more for its divergence from than for its conformity to accepted theory. The western end of the Brick Flat ore body is characterized by the highest positive potential found in the area. A negative potential had been predicted for this area because the western end of the Brick Flat ore body is topographically higher than the eastern end. The Brick Flat reservoir, located on the surface about over the midpoint of the ore body, should establish a pseudo water table that would overlie the eastern end of the ore body. Had this assumption been correct, we should have had a negative potential at the western end and a positive at the eastern end of the ore body. What was found was almost the reverse condition. The major negative lows are not centered over known ore, nor do they conform to points of nearest proximity to ore because of topographic factors. The negative zone trends from southwest to northeast between 2,000E 3,000N and

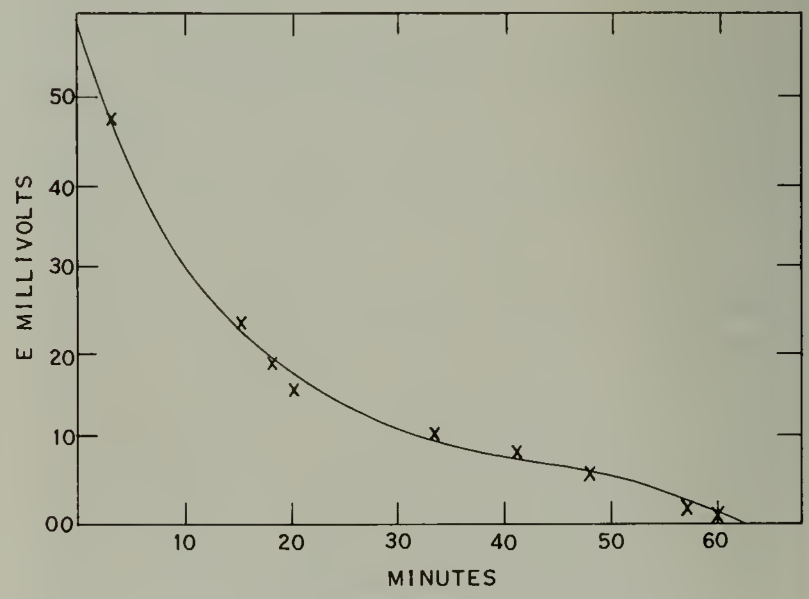


Figure 11. Graph of potential-time study at station 630.

5,000E 5,000N (pl. 8). The negative zone lies along the south and southwest edge of the ore bodies and conforms more to the gossanized area than to the ore.

Magnetic observations

Magnetic observations did not appear to offer much promise because the magnetic contrast between ore and country rock was too small, and where magnetite concentrations were known to occur they showed no recognizable genetic relation to the sulfides. It is generally accepted that quantitative depth determinations cannot be made in magnetic prospecting. The limiting depth at which a magnetic body may be detected is dependent upon its size, shape, and magnetic susceptibility.

The highly magnetic mineral maghemite is known to occur in the gossan at Iron Mountain, but its genetic relationship to the sulfides is not known, so it would seem to be a questionable guide to use in prospecting for ore. Known occurrences of this mineral led to the more extended magnetic survey in the 1952 field season.

An Askania vertical-intensity magnetometer was used to make the field measurements. A total of 486 magnetic stations were occupied. Most of these stations were in locations that had previously been occupied in the natural-potential survey. No attempt has been made to prepare an isogram map since the distribution of stations was too thin to justify such a map.

Three irregular transverses, A-B, B-C, and D-E, have been plotted together with their corresponding topographic profiles and geologic sections (pl. 8). Traverse A-B is essentially a south-to-north traverse starting over the Copley Greenstone and ending over the Richmond ore body. This traverse illustrates well the lack of magnetic contrast between rocks of the Copley Greenstone and the Balaklala Rhyolite. Traverse B-C is an east-to-west continuation of A-B along the Richmond and Brick Flat ore bodies and into the gossanized area of the Old Mine. The outstanding feature of this traverse is its erratic nature, which is characteristic of all magnetic readings in the mineralized zone of this mine area. Traverse D-E is another south-to-north traverse which crosses the western end of the Brick Flat ore body. This traverse confirms the observations of the other traverses and emphasizes the magnetic homogeneity of the Copley Greenstone and the Balaklala Rhyolite.

In addition to crossing the ore bodies, these traverses also crossed the Camden, J, Scott, and South faults. The Camden, J, and Scott faults cut the ore bodies at points on the traverses. The South fault does not cut any known ore bodies. No definite or significantly different pattern of magnetic disturbance was registered over any of the faults.

There is no significant correlation between topography and either magnetic or natural-potential measurements. Also there is no obvious correlation between magnetic and natural-potential measurements.

The most obvious feature of the entire survey is the very erratic nature of magnetic readings over the mineralized area.

Conclusions

Resistivity measurements are considered to be of doubtful value. Natural-potential anomalies are present and probably result from chemical activity associated with mineralization. They do not outline the ore body but, judiciously used by an experienced geophysicist, they should be a valuable guide in prospecting for other ore bodies. Magnetic readings over the mineralized ore were found to be much more erratic than in adjacent areas. This erratic pattern did seem to be characteristic of the mineralized area but it is questionable if the same would be true of more deeply buried ore bodies.

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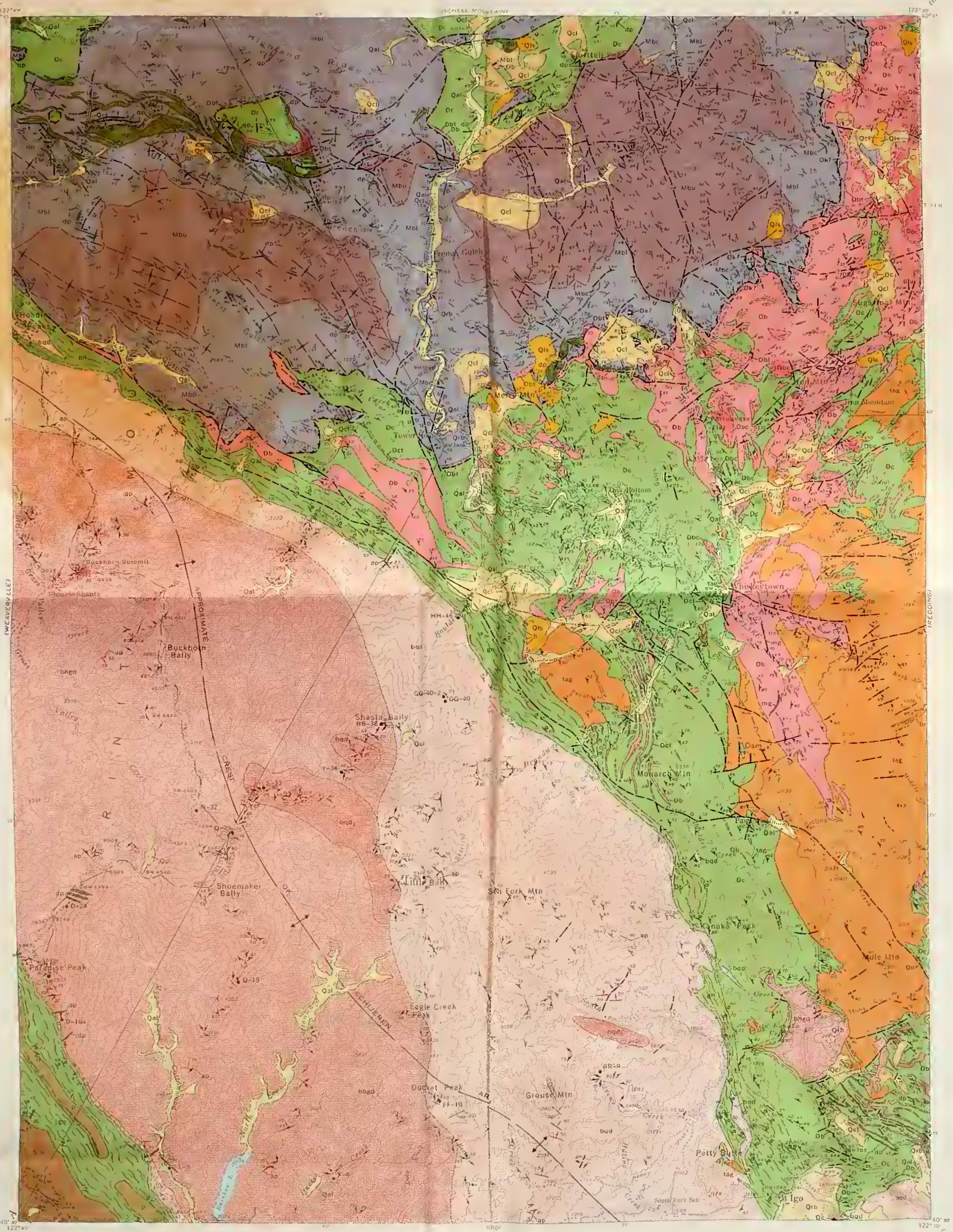
DEPARTMENT OF THE INTERIOR
UNITED STATES GEOLOGICAL SURVEY

PREPARED IN COOPERATION WITH
THE STATE OF CALIFORNIA
DIVISION OF MINES AND GEOLOGY

SPECIAL REPORT 85
PLATE 1

GEOLOGY OF THE
FRENCH GULCH QUADRANGLE
CALIFORNIA
GO-336



Base by U S Geological Survey, 1944
Outline of Whiskeytown Lake, 1963

Geology mapped in 1945–50
and 1956–57

EXPLANATION

QUATERNARY

Recent

Qls Qal Qcl

Unconsolidated deposits

Qcl, soil, slope wash, and talus (mapped only where bedrock geology is effectively obscured)
Qal, sand and gravel in stream beds
Qls, landslide

UNCONFORMITY

Pleistocene

Qrb

Red Bluff formation

Older semiconsolidated gravels that may be correlative

UNCONFORMITY

CRETACEOUS

K

Conglomerate and sandstone

UNCONFORMITY

JURASSIC OR CRETACEOUS

dp

"Birdseye" porphyry

Diorite porphyry, dacite porphyry, andesite porphyry

h

Hornblendite

qp

Quartz porphyry

ap

Aplite dike, showing vertical and inclined attitude

mg

Metagabbro and lamprophyre dikes

bhgd bqd bqd₁

Shasta Bally batholith

bhgd, biotite hornblende granodiorite and quartz diorite
bqd, coarse biotite granodiorite and quartz diorite
bqd₁, fine biotite granodiorite and quartz diorite

gn

Gneiss and amphibolite derived from Copley, Balaklala, and Bragdon formations

in

Injected rocks and breccia

p

Peridotite

tag br

Mule Mountain stock

tag, trondhjemite and albite granite
br, intrusive breccia

UNCONFORMITY

MISSISSIPPIAN
CARBONIFEROUS

Mbp Mbu Mbl Mbc

Bragdon formation

Mbu, upper unit consisting of abundant conglomerate and sandstone, interbedded with siltstone and shale
Mbl, lower unit consisting mostly of shale, mudstone, and siltstone, with subordinate tuff and conglomerate
Mbc, conglomerate bed in lower unit
Mbp, phyllite derived from Bragdon formation by contact metamorphism of Shasta Bally batholith

UNCONFORMITY

DEVONIAN

Dk?

Kennett(?) formation

Gray and black cherty shale

Dbc Db Dbt

Balaklala rhyolite

Dbc, porphyritic quartz keratophyre containing quartz phenocrysts larger than 4 mm
Db, nonporphyritic quartz keratophyre and quartz keratophyre containing quartz phenocrysts ranging from <1 to 4 mm
Dbt, tuff and tuffaceous shale
Units Dbc and Db include much coarse volcanic breccia. The Balaklala rhyolite intertongues with and locally intrudes the Copley greenstone. Layers of greenstone interbedded in the Balaklala are mapped as Copley greenstone. Is also found as probable flows in Kennett(?) and Bragdon formations

DEVONIAN(?)

Dc Dct

Copley greenstone

Dc, keratophyre, spilite, and metaandesite (includes volcanic breccia and agglomerate facies)
Dct, tuff, shaly tuff, and shale
The Copley greenstone intertongues with the Balaklala rhyolite and contains numerous sheets of quartz porphyry indistinguishable from the Balaklala. These are here mapped as Balaklala

UNCONFORMITY(?)

PRE-SILURIAN

Sch

Abrams mica schist and Salmon(?) hornblende schist, undifferentiated

Contact, showing dip

Long dashed where approximately located, short dashed where indefinite; dotted where concealed

Fault, showing dip

Dashed where approximately located; queried where probable; dotted where concealed. U, upthrown side, D, downthrown side

Vertical fault

Spring Creek thrust

Mainly between Bragdon formation and underlying rocks, but in places between Copley greenstone and tuff of the Balaklala rhyolite. Sawteeth on upper plate. Queried where doubtful, dotted where concealed

Anticline, showing position of crest line

Dashed where approximately located

Syncline, showing position of trough

Dashed where approximately located, dotted where covered by slope wash or alluvium

Plunge of minor anticline

Plunge of minor syncline

Plunge of fold axis

Inclined Vertical
Attitude of beds

Strike and dip of beds and plunge of lineation

Inclined Vertical
Attitude of schistosity

Strike and dip of schistosity and plunge of lineation

Inclined Vertical
Attitude of compositional layering in gneiss

Strike and dip of compositional layering in gneiss, and plunge of lineation

Inclined Vertical
Attitude of primary flow banding in granitic rocks as shown by alined crystals or inclusions

Strike and dip of sheeting

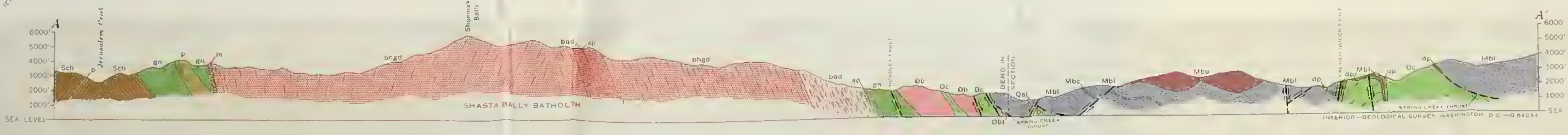
Inclined Vertical
Attitude of cleavage

Inclined Vertical
Attitude of joints

Sample localities

QUADRANGLE LOCATION

Note: Outline of Whiskeytown Lake shown by dashed blue line.



INTERIOR—GEOLOGICAL SURVEY WASHINGTON D C —G 64084

This map is plate 1 of Special Report 85, published by the California Division of Mines and Geology.
It is also sold (without text) by the U.S. Geological Survey.

GEOLOGY OF THE FRENCH GULCH QUADRANGLE, CALIFORNIA

SCALE 1:62 500

½ 0 1 2 3 4 5 MILES

1 .5 0 1 2 3 4 5 KILOMETERS

CONTOUR INTERVAL 50 FEET
DATUM IS MEAN SEA LEVEL

By

J. P. Albers, A. R. Kinkel, Jr., A. A. Drake, and W. P. Irwin

1964

GEOLOGY OF THE
FRENCH GULCH QUADRANGLE
CALIFORNIA
GO-336

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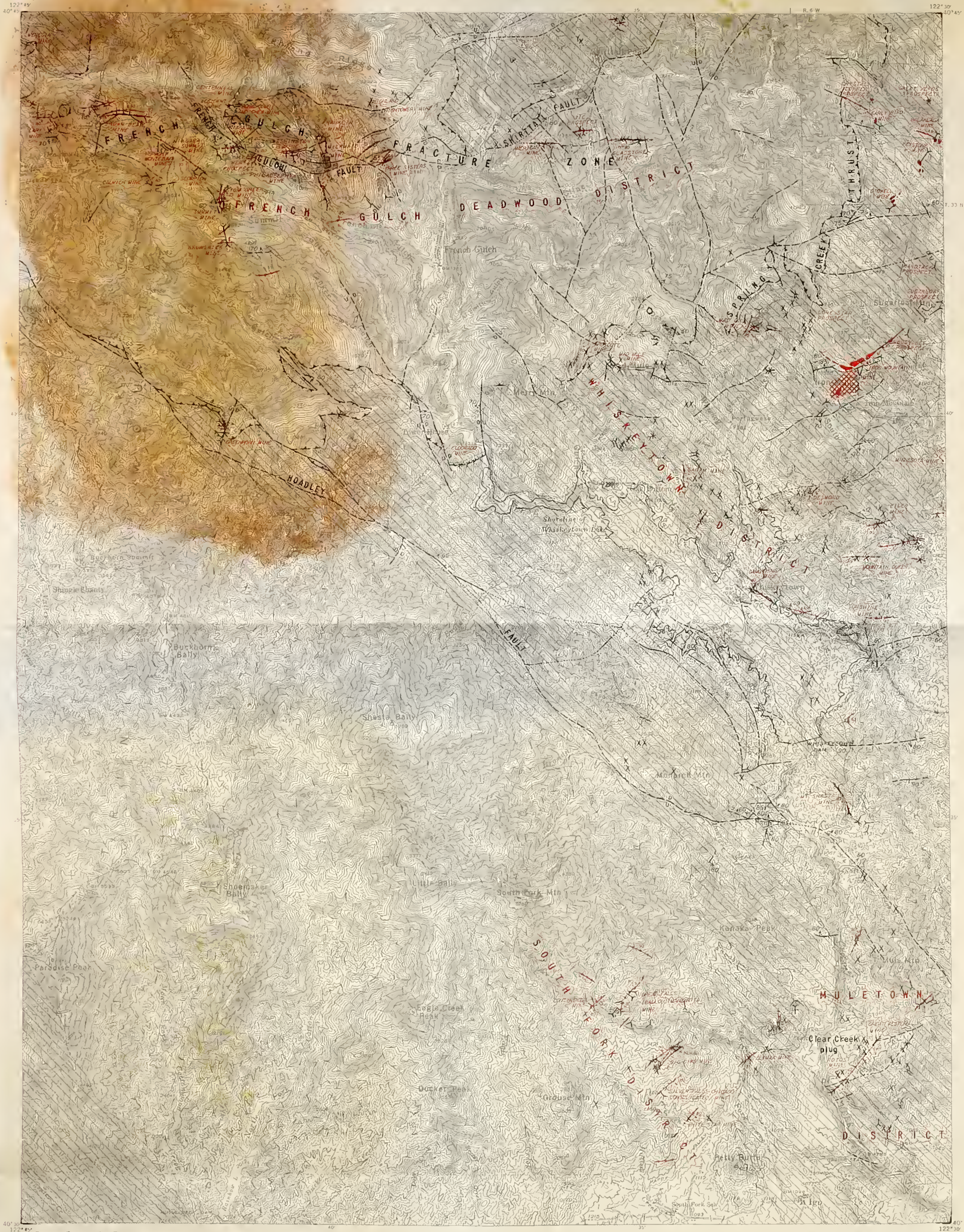


Base by Topographic Division
U.S. Geological Survey, 1944
Whiskeytown dam and lake,
and U.S. 299, 1963

SCALE 1:62 500
1 ½ 0 1 2 3 4 MILES

CONTOUR INTERVAL 50 FEET
DATUM IS MEAN SEA LEVEL

Geology by J. P. Albers, A. R. Kinkel, Jr.,
A. A. Drake, and W. P. Irwin,
1945–50 and 1956–57

EXPLANATION

🟥 "Birdseye" porphyry and quartz porphyry dikes and sills

▨ Shasta Bally batholith

▨ Mule Mountain stock

☐ Bragdon and Kennett(?) Formations, undifferentiated

▨ Balaklala and Copley Formations, and schist, gneiss, migmatite, and peridotite, undifferentiated

▨ Gossan derived from massive sulfide

Known massive sulfide bodies
Projected to surface

Quartz vein, showing dip
Projected to surface

Contact
Dashed where approximately located, dotted where concealed by unconsolidated deposits (not shown)

Fault, showing dip
Dashed where approximately located; dotted where concealed; U, upthrown side; D, downthrown side

Vertical fault

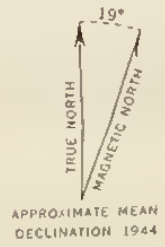
Spring Creek thrust fault
Sawteeth on upper plate; queried where doubtful

Known or probable feeder fault for massive sulfide

Underground workings
Projected to surface

Portal of adit

X
Pit or trench



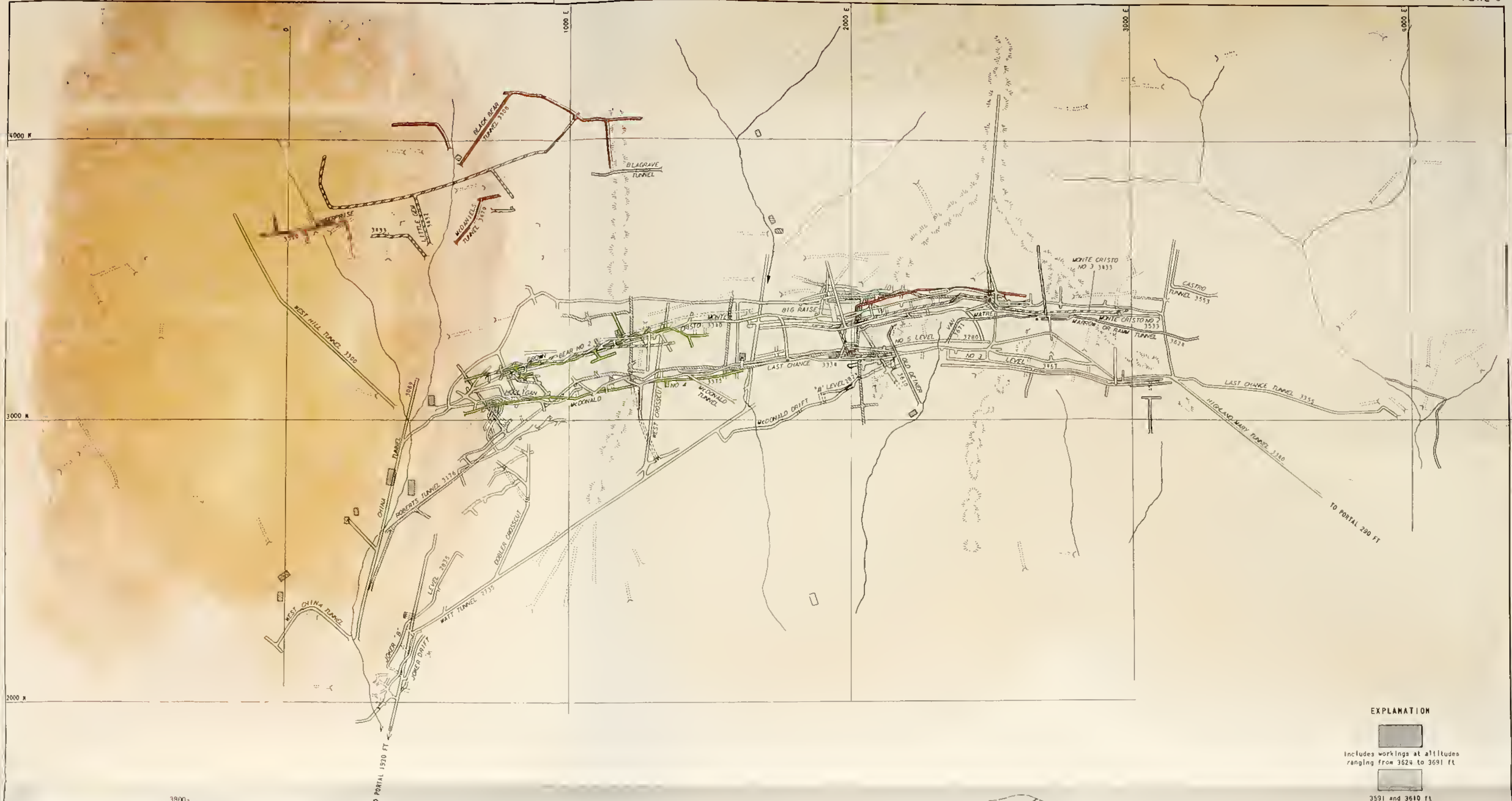
MAP SHOWING GENERALIZED GEOLOGY AND DISTRIBUTION OF BASE AND PRECIOUS METAL MINES AND PROSPECTS, FRENCH GULCH QUADRANGLE, SHASTA AND TRINITY COUNTIES, CALIFORNIA

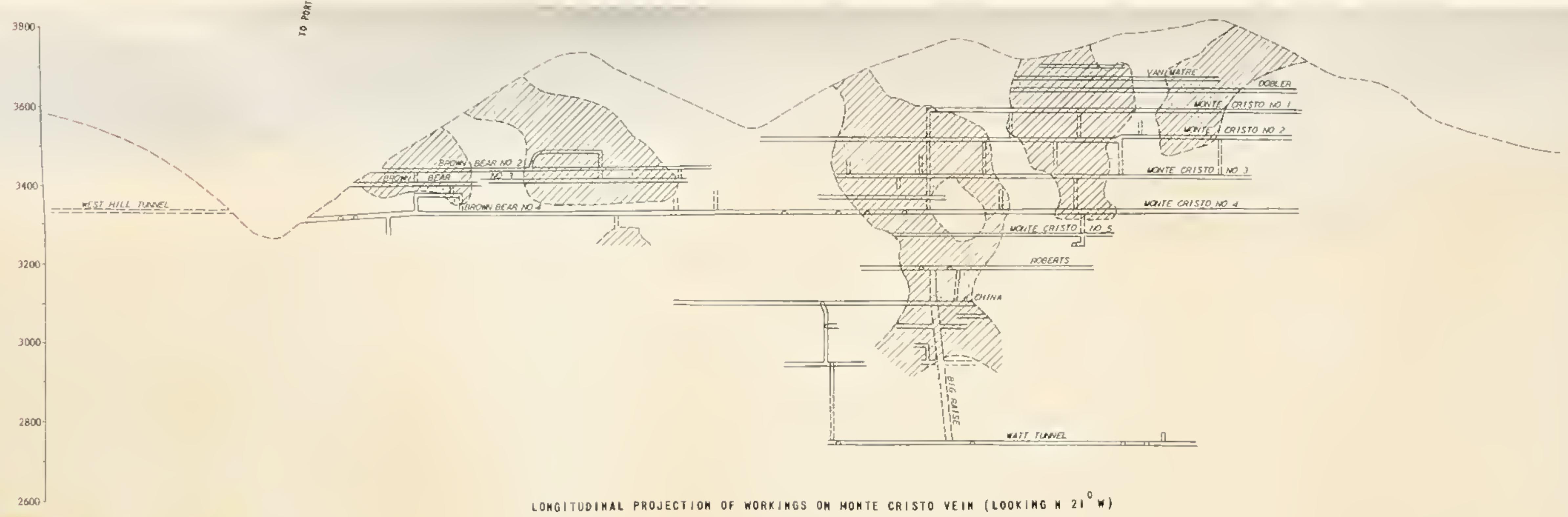
DIVISION OF MINES AND GEOLOGY
IAN CAMPBELL, STATE GEOLOGIST

THE RESOURCES AGENCY OF CALIFORNIA
DEPARTMENT OF CONSERVATION

UNITED STATES DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY

SPECIAL REPORT 85
PLATE 3

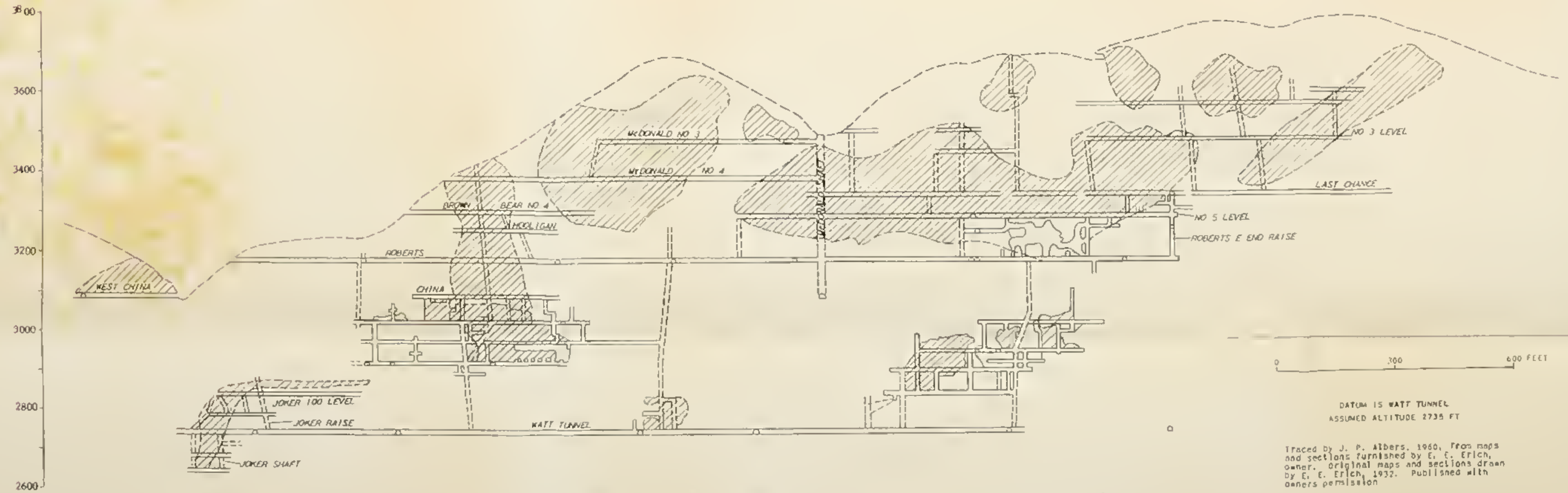




LONGITUDINAL PROJECTION OF WORKINGS ON MONTE CRISTO VEIN (LOOKING N 21° W)

EXPLANATION

▒	Includes workings at altitudes ranging from 3624 to 3691 ft
░	3591 and 3610 ft
☐	3533, 3553, and 3556 ft
🟥	3479, 3500, 3508, and 3510 ft
☐	3467 and 3473 ft
▨	3419, 3432, and 3433 ft
🟩	3375 and 3390 ft
☐	3300, 3302, 3334, 3340, 3352, and 3355 ft
☐	3258 and 3280 ft
▒	3176 ft
☐	3089 ft
☐	2949 ft
▧	2823, 2827, and 2835 ft
☐	2735 ft
▨	Stoped area



0 300 600 FEET

DATUM IS WATT TUNNEL
ASSUMED ALTITUDE 2735 FT

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LONGITUDINAL PROJECTION OF WORKINGS ON THE LAST CHANCE VEIN (LOOKING N 21° W)

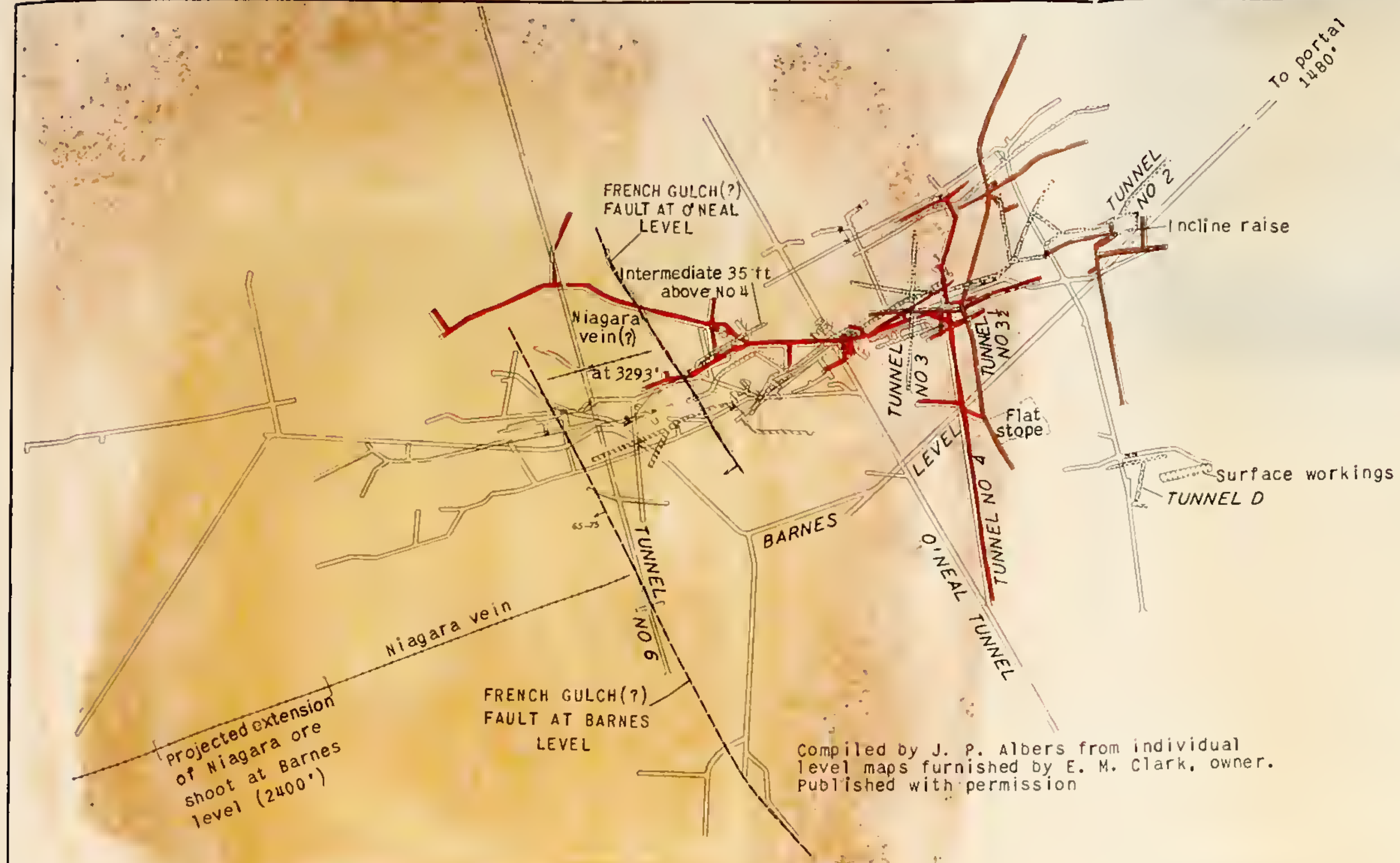
COMPOSITE MAP AND LONGITUDINAL PROJECTIONS OF THE BROWN BEAR MINE, TRINITY COUNTY, CALIFORNIA

DIVISION OF MINES AND GEOLOGY
IAN CAMPBELL, STATE GEOLOGIST

THE RESOURCES AGENCY OF CALIFORNIA
DEPARTMENT OF CONSERVATION

UNITED STATES DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY

SPECIAL REPORT 85
PLATE 4



Compiled by J. P. Albers from individual level maps furnished by E. M. Clark, owner. Published with permission

COMPOSITE PLAN OF THE NIAGARA MINE

EXPLANATION

Tunnel No 2 (3393')
Tunnel No 3 (3336')
Tunnel D (altitude unknown)

Tunnel No 3½ (3308')
Tunnel No 5 (3301')

Tunnel No 6 (3293')

Tunnel No 4 (3204')

Tunnel No 1 (3172')

Station 1 level (3118')

Station 2 level (3063')

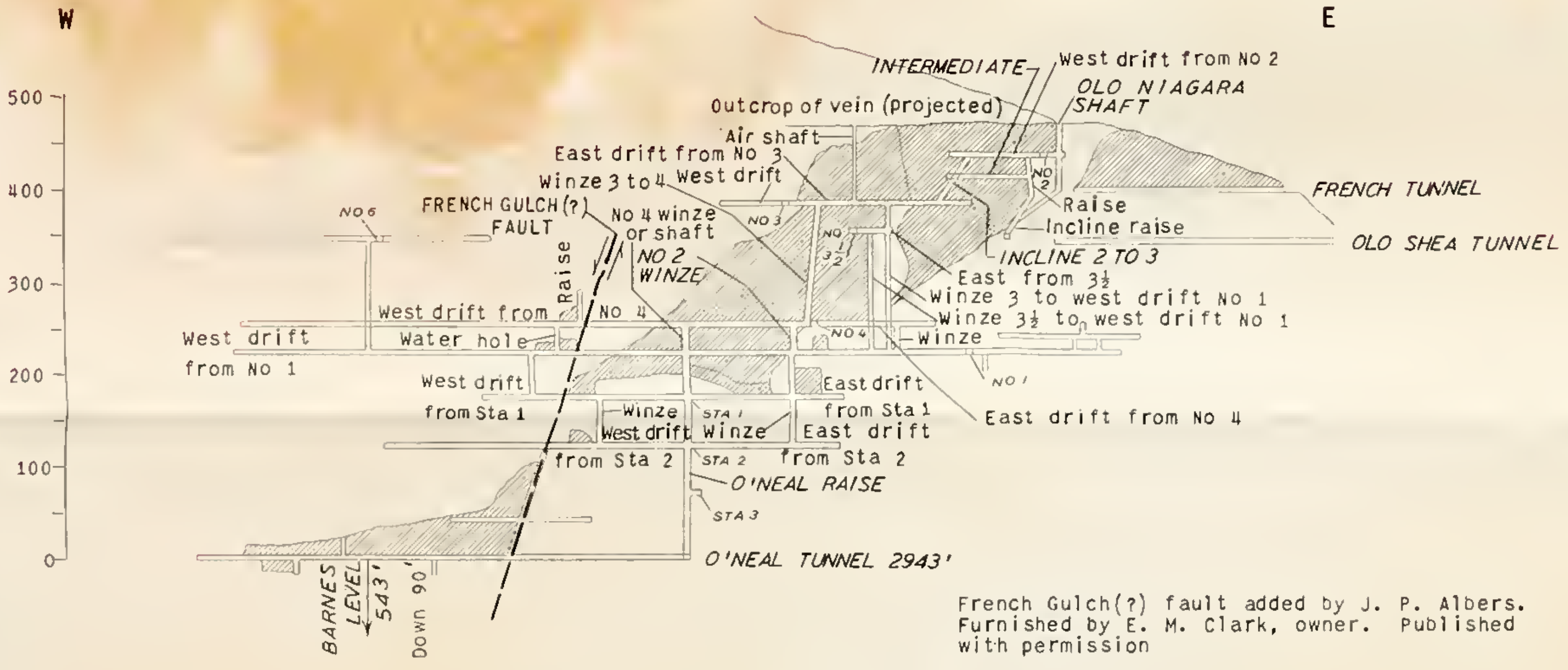
Station 3 level (3013')
Intermediate above No 4 (3239')

O'Neal Level

Barnes level (2400')

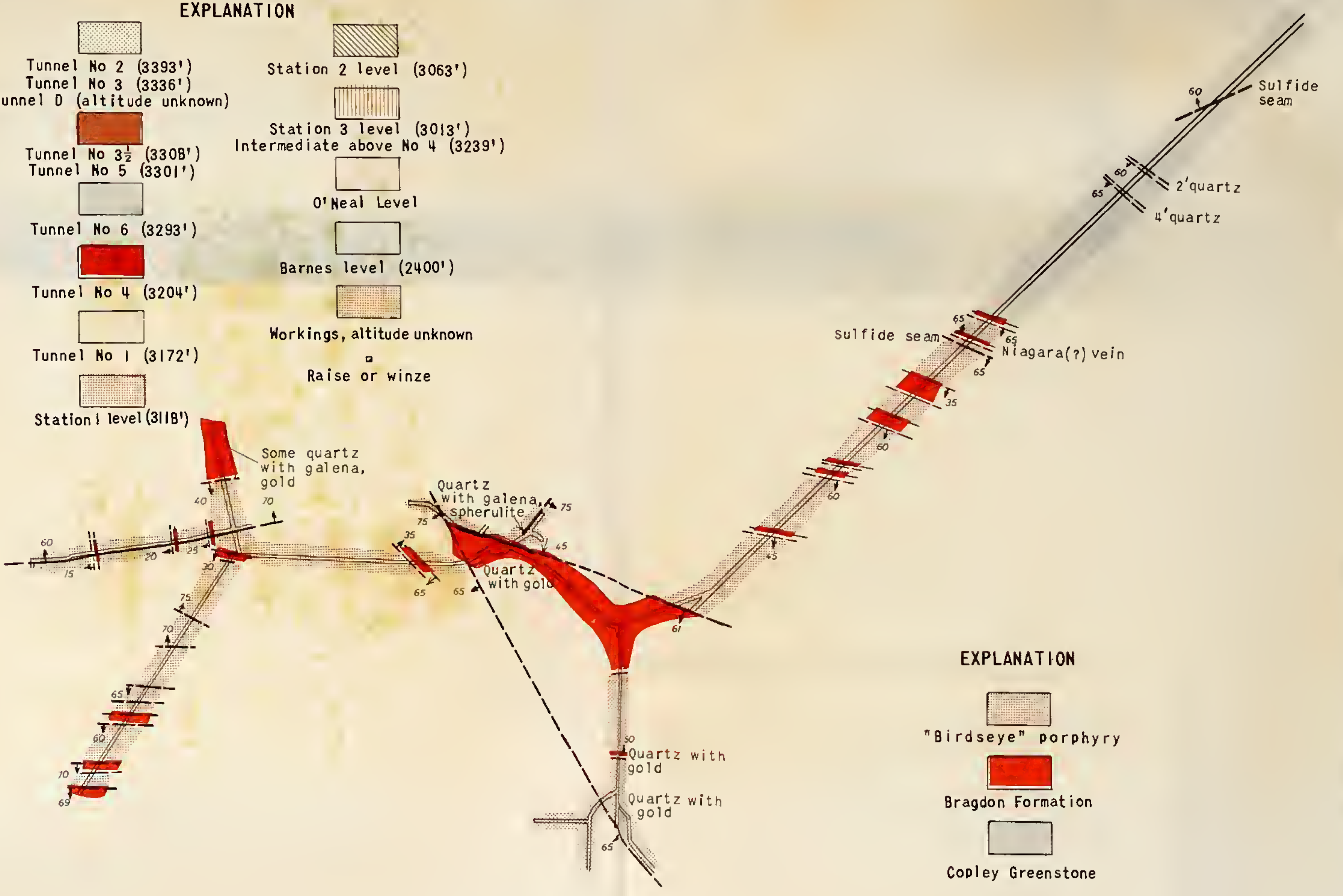
Workings, altitude unknown

□ Raise or winze



French Gulch(?) fault added by J. P. Albers. Furnished by E. M. Clark, owner. Published with permission

LONGITUDINAL PROJECTION OF THE NIAGARA MINE



EXPLANATION

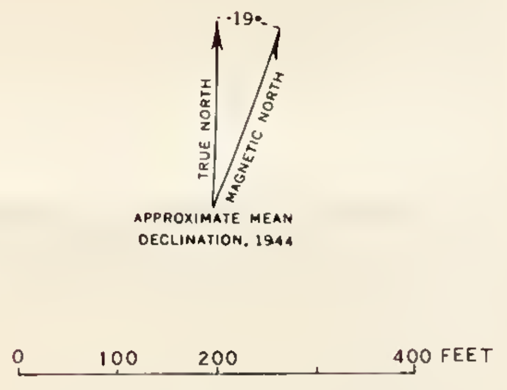
"Birdseye" porphyry

Bragdon Formation

Copley Greenstone

Fault, showing dip

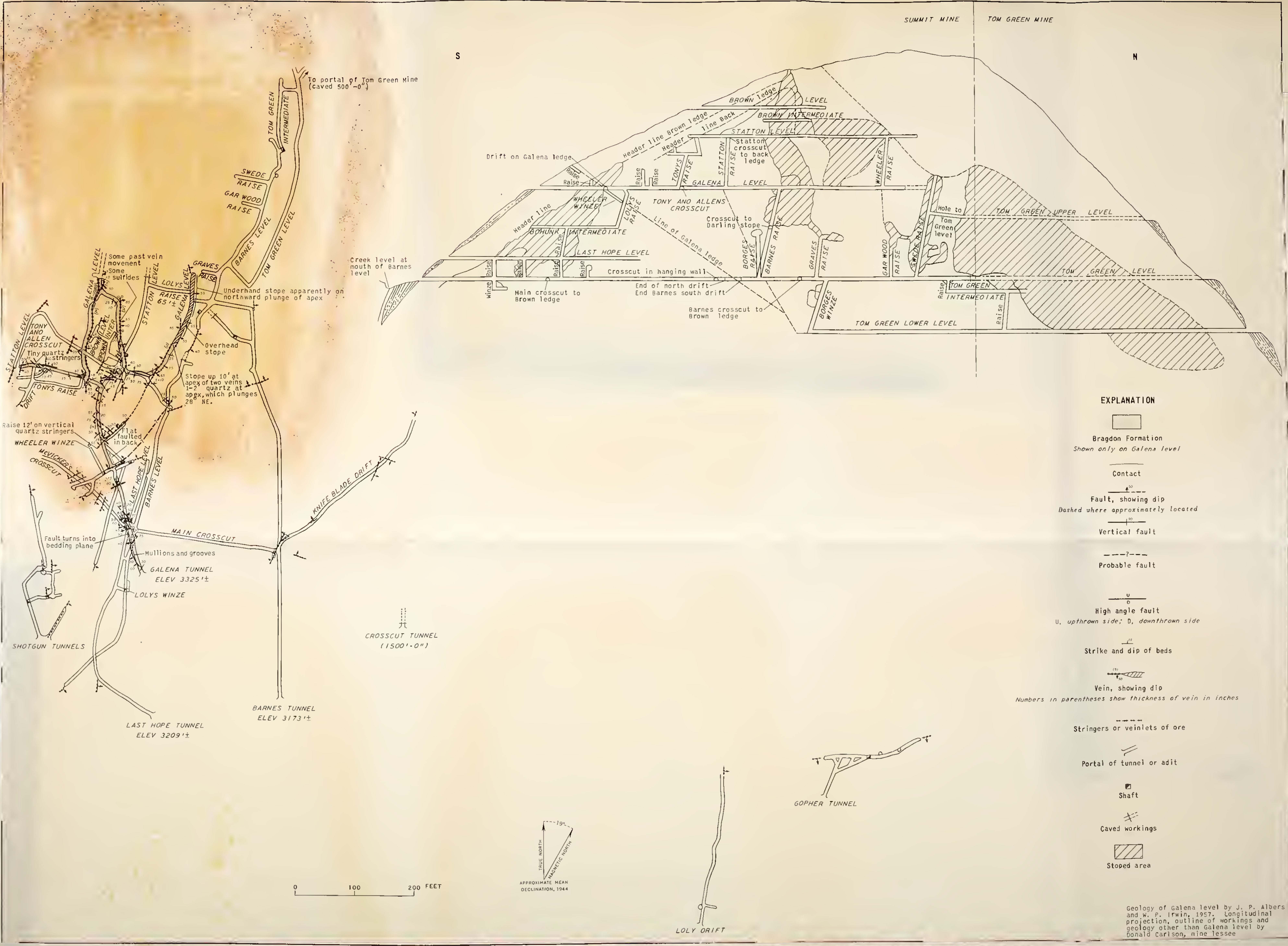
GEOLOGIC MAP OF THE BARNES LEVEL



DATUM IS BARNES TUNNEL LEVEL
(ALTITUDE APPROXIMATELY 2400 FT)

Geology by Arthur W. Johnston, 1930. Map and geology furnished by E. M. Clark, owner. Published with permission

COMPOSITE PLAN, LONGITUDINAL PROJECTION, AND GEOLOGIC MAP OF THE BARNES LEVEL, NIAGARA MINE, SHASTA COUNTY, CALIFORNIA



Geology of Galena level by J. P. Albers and W. P. Irwin, 1957. Longitudinal projection, outline of workings and geology other than Galena level by Donald Carlson, mine lessee

MAP AND LONGITUDINAL PROJECTION OF THE SUMMIT MINE, SHASTA COUNTY, CALIFORNIA

DIVISION OF MINES AND GEOLOGY
IAN CAMPBELL, STATE GEOLOGIST

STATE OF CALIFORNIA
THE RESOURCES AGENCY
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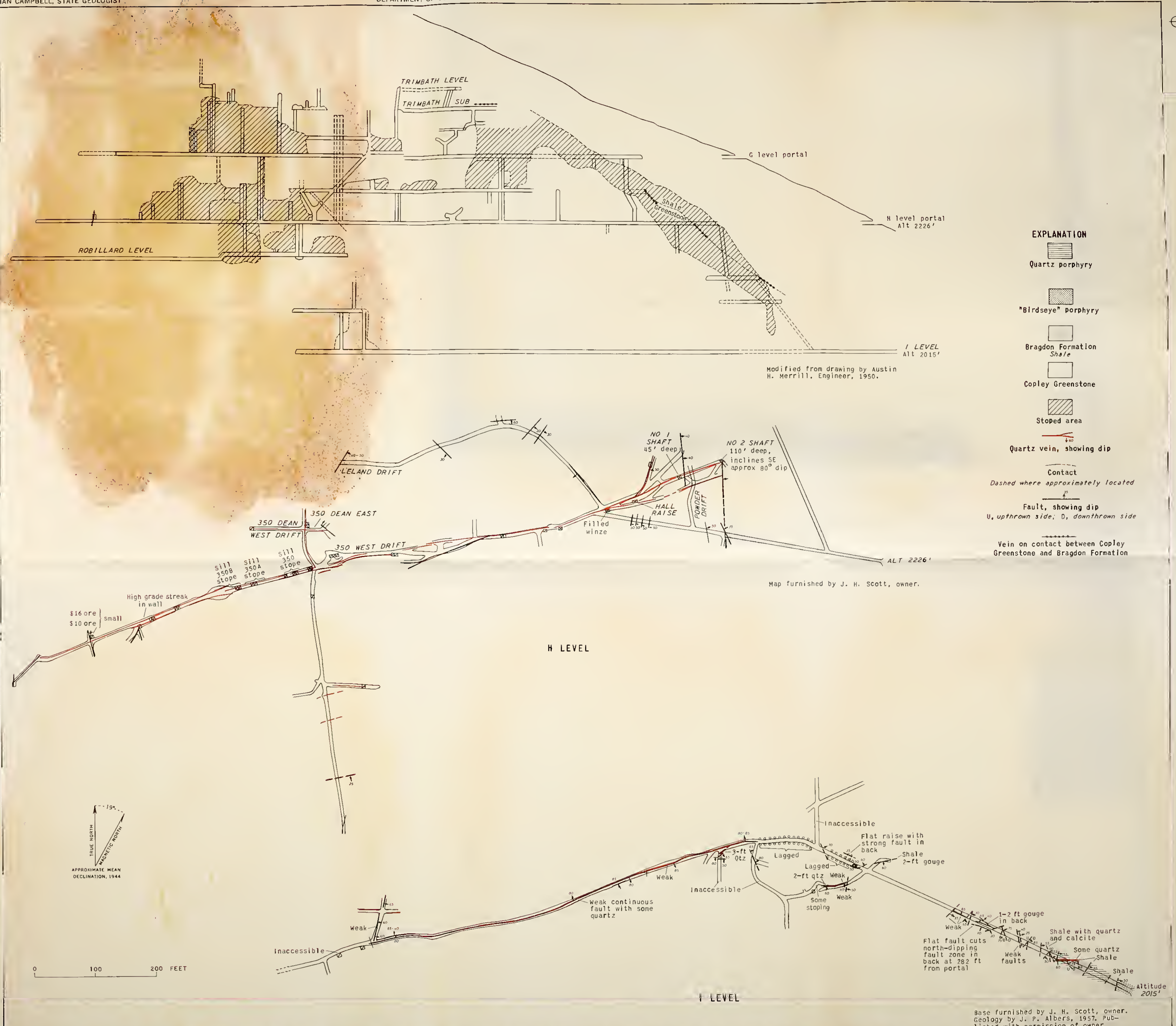
SPECIAL REPORT 85
PLATE 6

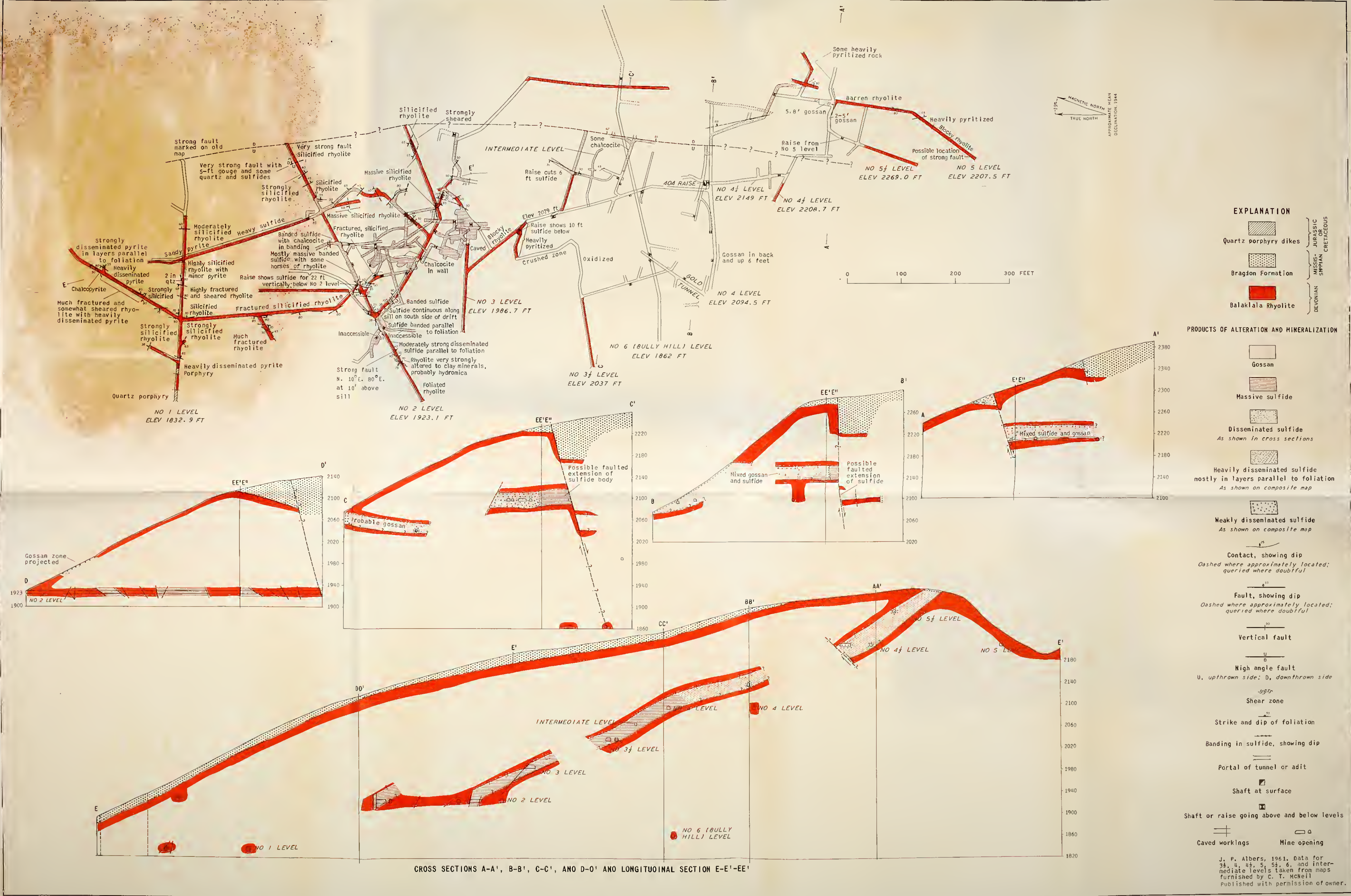


Modified from drawing by Austin H. Merrill, Engineer, 1950.

Map furnished by J. H. Scott, owner.

Base furnished by J. H. Scott, owner. Geology by J. P. Albers, 1957. Published with permission of owner

GEOLOGIC MAPS OF H AND I LEVELS AND LONGITUDINAL PROJECTION OF THE WASHINGTON MINE, SHASTA COUNTY, CALIFORNIA


Strong fault marked on old map
Very strong fault
Silicified rhyolite
Very strong fault with 5-ft gouge and some quartz and sulfides
Strongly silicified rhyolite.
Silicified rhyolite
Massive silicified rhyolite
Silicified rhyolite
Strongly sheared
Moderately silicified rhyolite
Heavy sulfide
Sandy pyrite
Strongly disseminated pyrite in layers parallel to foliation
Heavily disseminated pyrite
Chalcopyrite
E
Much fractured and somewhat sheared rhyolite with heavily disseminated pyrite
Highly silicified rhyolite with minor pyrite
2 in qtz
Strongly silicified
Highly fractured and sheared rhyolite
Silicified rhyolite
Strongly silicified rhyolite
Strongly silicified rhyolite
Much fractured rhyolite
Fractured silicified rhyolite
Heavily disseminated pyrite
Porphyry
Quartz porphyry
NO 1 LEVEL
ELEV 1832.9 FT
Massive silicified rhyolite
Fractured, silicified rhyolite
Banded sulfide with chalcocite in banding
Mostly massive banded sulfide with some horses of rhyolite
Raise shows sulfide for 22 ft vertically below No 2 level
Chalcocite in wall
Caved
Blocky rhyolite
Banded sulfide
Sulfide continuous along sill on south side of drift
Sulfide banded parallel to foliation
Inaccessible
Inaccessible
Moderately strong disseminated sulfide parallel to foliation
Rhyolite very strongly altered to clay minerals, probably hydromica
Strong fault N. 10° E. 80° E. at 10' above sill
Foliated rhyolite
NO 2 LEVEL
ELEV 1923.1 FT
NO 3 LEVEL
ELEV 1986.7 FT
INTERMEDIATE LEVEL
Raise cuts 6 ft sulfide
Some chalcocite
Elev 2029 ft
Raise shows 10 ft sulfide below
Heavily pyritized
Crushed zone
Oxidized
NO 3½ LEVEL
ELEV 2037 FT
404 RAISE
NO 4¼ LEVEL
ELEV 2149 FT
NO 4½ LEVEL
ELEV 2208.7 FT
GOLD TUNNEL
Gossan in back and up 6 feet
NO 4 LEVEL
ELEV 2094.5 FT
NO 6 (BULLY HILL) LEVEL
ELEV 1862 FT
Some heavily pyritized rock
5.8' gossan
2-5' gossan
Barren rhyolite
Heavily pyritized
Blocky rhyolite
Raise from No 5 level
Possible location of strong fault
NO 5½ LEVEL
ELEV 2269.0 FT
NO 5 LEVEL
ELEV 2207.5 FT
A'
B'
C'
E'
A
B
C
MAGNETIC NORTH
TRUE NORTH
19½°
APPROXIMATE MEAN DECLINATION, 1944
0
100
200
300 FEET
D
D'
EE'E"
Gossan zone projected
NO 2 LEVEL
1923
1900
Probable gossan
Possible faulted extension of sulfide body
Mixed gossan and sulfide
Possible faulted extension of sulfide
Mixed sulfide and gossan
E
DD'
E'
CC'
BB'
AA'
E'
NO 1 LEVEL
NO 2 LEVEL
NO 3 LEVEL
NO 3½ LEVEL
INTERMEDIATE LEVEL
NO 4½ LEVEL
NO 4 LEVEL
NO 5½ LEVEL
NO 5 LEVEL
NO 6 (BULLY HILL) LEVEL
EXPLANATION
Quartz porphyry dikes
JURASSIC OR CRETACEOUS
Bragdon Formation
MISSISSIPPIAN
Balaklala Rhyolite
DEVONIAN
PRODUCTS OF ALTERATION AND MINERALIZATION
Gossan
Massive sulfide
Disseminated sulfide
As shown in cross sections
Heavily disseminated sulfide mostly in layers parallel to foliation
As shown on composite map
Weakly disseminated sulfide
As shown on composite map
Contact, showing dip
Dashed where approximately located; queried where doubtful
Fault, showing dip
Dashed where approximately located; queried where doubtful
Vertical fault
High angle fault
U, upthrown side; D, downthrown side
Shear zone
Strike and dip of foliation
Banding in sulfide, showing dip
Portal of tunnel or adit
Shaft at surface
Shaft or raise going above and below levels
Caved workings
Mine opening

CROSS SECTIONS A-A', B-B', C-C', AND D-D' AND LONGITUDINAL SECTION E-E'-EE'

J. P. Albers, 1961. Data for 3½, 4, 4½, 5, 5½, 6, and intermediate levels taken from maps furnished by C. T. McNeil
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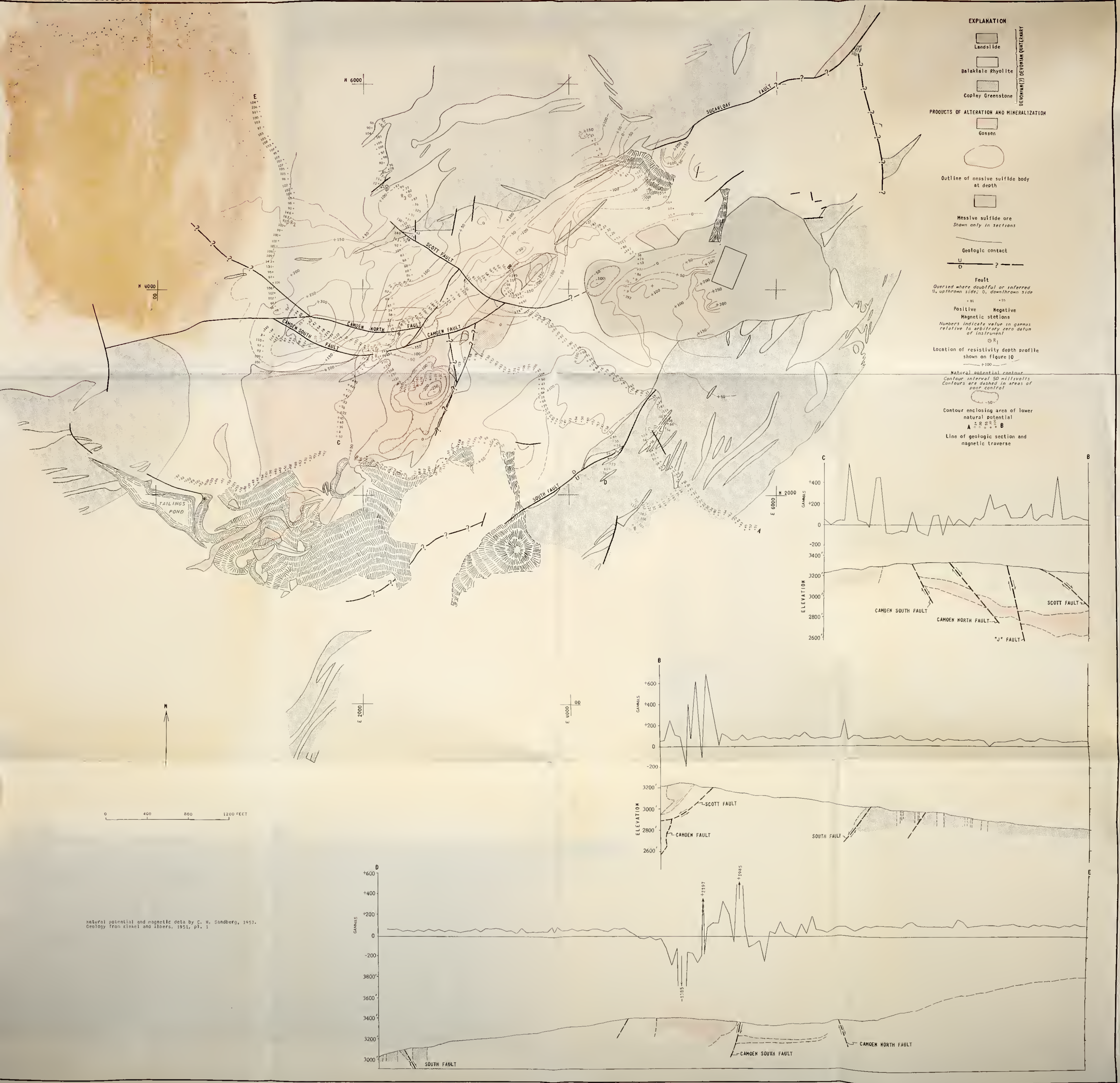
COMPOSITE MAP AND SECTIONS OF THE GREENHORN MINE, SHASTA COUNTY, CALIFORNIA

DIVISION OF MINES AND GEOLOGY
IAN CAMPBELL, STATE GEOLOGIST

THE RESOURCES AGENCY OF CALIFORNIA
DEPARTMENT OF CONSERVATION

UNITED STATES DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY

SPECIAL REPORT 85
PLATE 8


EXPLANATION
Landslide
Balaklala Rhyolite
Copley Greenstone
QUATERNARY
DEVONIAN
DEVONIAN(?)
PRODUCTS OF ALTERATION AND MINERALIZATION
Gossan
Outline of massive sulfide body at depth
Massive sulfide ore
Shown only in sections
Geologic contact
U
D
Fault
Queried where doubtful or inferred
U, upthrown side; D, downthrown side
Positive
Negative
Magnetic stations
Numbers indicate value in gammas relative to arbitrary zero datum of instrument
R1
Location of resistivity depth profile shown on figure 10
+100
Natural potential contour
Contour interval 50 millivolts
Contours are dashed in areas of poor control
-50
Contour enclosing area of lower natural potential
A
B
Line of geologic section and magnetic traverse
SUGARLOAF FAULT
SCOTT FAULT
CAMDEN NORTH FAULT
CAMDEN SOUTH FAULT
CAMDEN FAULT
SOUTH FAULT
TAILINGS POND
N 6000
N 4000
N 2000
E 2000
E 4000
E 6000
00
N
0
400
800
1200 FEET
A
B
C
D
E
GAMMAS
ELEVATION
+600
+400
+200
0
-200
3800'
3600'
3400'
3200'
3000'
2800'
2600'
"J" FAULT
+2197
+1945
-1585

Natural potential and magnetic data by C. H. Sandberg, 1957.
Geology from Kinkel and Albers, 1951, pl. 1

MAP, GEOLOGIC SECTIONS, AND NATURAL-POTENTIAL AND MAGNETIC SURVEYS OF IRON MOUNTAIN MINE AREA, SHASTA COUNTY, CALIFORNIA

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